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# Bulletin

*of the*

# Torrey Botanical Club

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 86, NO. 2, PP. 81–87 MARCH, 1959

# POLYPLOIDY IN GASTERIA AND HAWORTHIA[1]

HERBERT PARKES RILEY

During the last thirty years, many observations on the chromosome cytology of the tribe Aloineae of the family Liliaceae have been made, most of which were carried out on plants growing in various botanical gardens of Europe, Japan and the United States. Of the studies that included a large number of individuals, species and varieties, only those of Müller (1941, 1945) and the writer (Riley 1959a) on *Aloë* were carried out entirely or partly in South Africa where most of this tribe grows wild.

One of the problems arising from a consideration of chromosome numbers in the Aloineae and their bearing on the evolution of the group is the extent of polyploidy. Early studies seemed to indicate that all the species had fourteen somatic chromosomes but since 1938 it has been clear that polyploids exist and that they are rather numerous in at least two of the sections of *Haworthia*. A few years ago, the writer was able to conduct some investigations in the field which have some bearing on the frequency of polyploidy. His results on *Aloë* have been published elsewhere (Riley 1959a). Those on *Gasteria* with a few observations on *Haworthia* and *Astroloba* will be given here. Results on *Aloë*, *Gasteria* and *Haworthia* have been given in a preliminary note (Riley 1958).

In *Aloë*, the combined data of the writer and other investigators show that less than three per cent of the recorded plants are polyploids and that the only polyploid species are *A. ciliaris* Haw. and *A. Tidmarshii* (Schonl.) Müller (= *A. ciliaris* var. *tidmarshii* Schonl.). Of 168 plants observed personally the only polyploids were two hexaploid plants of *A. ciliaris*.

In *Gasteria*, about seven per cent of 44 identified plants and four out of 32 unidentified plants reported by other investigators appear to be triploid or tetraploid. Twenty-four species and varieties and ten artificial interspecific hybrids studied by the writer (Riley 1959b) proved to be diploids;

[1] This paper is a joint contribution of the Departments of Botany of the University of Cape Town and the University of Kentucky and reports the results of work that was initiated and largely carried out while the writer held a Fulbright lectureship in South Africa in 1955–56. The writer is grateful to Dean M. M. White of Kentucky for the leave of absence, to the Joseph Henry Fund of the National Academy of Sciences in Washington for a grant to travel and collect material in southern Africa and to the Research Fund of the University of Kentucky for chemicals and glassware. Thanks are due to Professor W. E. Isaac of Cape Town for providing space and facilities in his department, to Mr. H. Herre of Stellenbosch and Mr. A. Berg of Pretoria for plants, to Mr. H. Hall of Kirstenbosch for caring for the plants shipped to the National Botanical Gardens and to Mrs. Eily Gledhill for conducting him to the plants of the Bushman's River Poort and neighboring regions.



[THE BULLETIN for January–February 1959 (86: 1–80) was issued March 5, 1959]

meiotic abnormalities were significantly more numerous in only two of the hybrids.

*Haworthia* apparently has a much higher percentage of polyploidy than *Aloë* or *Gasteria*. Of 110 species and varieties that have been identified by various investigators, 43 per cent have polyploid or aneuploid forms and most of them are in the Coarctatae and Tessellatae Sections. Of the remaining sections that have been studied, only three species or varieties out of 47 contain polyploids. Resende (1937) has reported on four and Snoad (1951) on 122 unidentified plants of which 47 are polyploids with $2n$ numbers ranging from 21 to 56.

The problems of cytotaxonomy and evolution in *Gasteria* and *Haworthia* are very similar to those of *Aloë*. In each genus one of the important questions that must be faced is the reliability of chromosome counts made from plants that had been collected in South Africa and shipped overseas perhaps a hundred years before the chromosome studies were made. Another serious obstacle to a study is the absence of a satisfactory monographic treatment of *Gasteria* and *Haworthia*. The South African species of *Aloë* have been monographed by Reynolds (1950), who studied them extensively under field conditions for many years, but much of the work that has been done on the other two genera has been carried out on botanical garden material. This procedure is unsatisfactory as there is much natural hybridization in both genera. Furthermore, botanical garden taxonomy cannot take into account ecological variants and rarely considers the age of the plant, an important consideration for these slow-growing succulents where the juvenile forms often show little similarity to the adult.

The need of a thorough taxonomic revision of *Gasteria* has recently been pointed out by Dr. Schelpe, Curator of the Bolus Herbarium of the University of Cape Town. The writer (Riley 1959b) has stated that Dr. Schelpe in a personal communication to him mentioned that preliminary observations indicated that apparently many species should be reduced to synonomy. Since the writer's manuscript was accepted for publication, Schelpe (1958) has published a preliminary study in which he states that the multiplicity of published species has resulted from the introduction of *Gasteria* to European gardens and the failure to appreciate ecological variability of the plants in the field under natural conditions. For example, in the *G. maculata* complex, whether an adult plant has distichous or spiral leaf arrangement and whether the leaves are long with acute apices or short with obtuse apices depends upon whether it was growing in a shady or in a sunny location. He also considers that *G. neliana* v. Poell. and *G. ernestii-ruschii* Dinter & v. Poell. are simply habitat variants of *G. pillansii* L. Bolus and that "*G. stayneri* and *G. armstrongii* are perpetuated juvenile forms of *G. beckeri* halted in their progress towards a full expression of adulthood by adverse climatic or soil factors." The writer has observed striking ecological

variation in *Aloë* where plants of *A. mitriformis* growing in the sun at Fransch Hoek Pass are bright red while those growing in the shade are a dull green. These ecological variants are not considered to be different species, but many such variants in *Gasteria* apparently are.

**Materials and methods.** Material for this study was obtained from several sources. Fifty plants resembling *G. zeyheri* (Salm.) Bak. were collected at the Bushman's River Poort in the eastern Cape Province and eight plants of *G. beckeri* Schonl. on the bank of the Kamtra River several miles away. The plants of the species resembling *G. zeyheri* were growing on a hillside and were partly shaded by the bush which forms the principal vegetation. Across the road at the foot of a hill and extending part way up were many plants of *Aloë ferox* and at the top of the hill, growing on a rocky krantz, were many specimens of *A. speciosa*. This was typical succulent country.

On the trip to the Bushman's River Poort the writer was accompanied by Mrs. Eily Gledhill, a lecturer in botany at Rhodes University. Although she has done extensive botanizing throughout the entire Fish River Scrub Valley and is familiar with the succulents of that region, she was unwilling to identify the species more closely than to say that it resembled *G. zeyheri*. An examination of the plants showed a large amount of minor variation which might result in part from introgressive hybridization and in part from different ecological conditions. One large leaf of each of 50 plants was cut off close to the base and shipped to the National Botanic Gardens at Kirstenbosch, near Cape Town, where the lower ends of the leaves were placed in moist sand through the kindness of Mr. H. Hall. Three months later each leaf had put out an abundance of roots from the cut surface. Slides were made from the root-tips of all fifty plants and a dozen leaves were dug up and shipped to Kentucky where they were again placed in moist sand; a few months afterwards each had developed another mass of roots. Several months later buds were formed at the cut surface and each leaf has now produced a number of small plants.

*Gasteria beckeri* was found at the top of the steep hill that forms one of the banks of the Kamtra River and was growing with *Aloë ferox* and *Haworthia reinwardtii*. Plants of *G. beckeri* are fairly small and were easily dug up and sent to Kirstenbosch.

One plant of an unidentified species was given to the writer by Mrs. Gledhill who had dug it up on the Cradock Road about six miles from Grahamstown. Four species of *Gasteria* were received from Mr. A. Berg, Curator of the Botanical Garden of the University of Pretoria. Thirty-nine plants of twenty different species and 47 unidentified plants were sent to the writer in Kentucky by Mr. H. Herre, Curator of the Botanical Garden of Stellenbosch University who has an excellent collection of succulents and has had a considerable amount of experience with them.

Seven plants of *Haworthia reinwardtii* (Salm.) Haw. were collected at

the Kamtra River, Alexandria District, Cape, and were grown for the writer at Kirstenbosch. Plants of eight other species were received from Mr. Berg.

One plant of an unidentified species of *Astroloba* (*Apicra*) was collected on the bank of the Great Fish River near the bridge at Committees.

Voucher specimens will be made of the plants that were shipped to Kentucky after they have passed the juvenile stage. Living plants will be kept, if possible, as well as herbarium specimens, since herbarium material of succulents is of slight value.

Slides were made from root tips by the technique described by Bhaduri and Ghosh (1954). Only roots from mature plants or from the cut surfaces of mature leaves were used.

Throughout this paper, Jacoben's (1954) Handbuch is used in listing species, varieties and hybrids of *Gasteria, Haworthia* and *Astroloba*. Although it is not the equivalent of a monograph, it can serve in lieu of one until such time as one appears. Although recognizing the importance of Schelpe's (1958) preliminary observations, the writer will accept the species listed in Jacobsen as valid until Schelpe or some one else has had time to make a complete revision of the genus.

**Observations.** The haploid chromosome complement of most *Gasteria, Haworthia* and *Astroloba* plants consists of four long and three much shorter chromosomes. Fifty-two plants of 21 different species of *Gasteria* and 98 unidentified individuals of that genus had fourteen chromosomes in their root tips, and are listed in Table 1. No polyploids were encountered. Chromosome counts were obtained for 24 plants of ten species that to the writer's knowledge have not previously been studied cytologically. They are indicated by an asterisk in Table 1.

This study is probably the only chromosome study on these genera that has been made on wild plants and carried out in South Africa. The fifty plants from the Bushman's River Poort, the eight of *G. beckeri*, the *Gasteria* collected along the Cradock road, the seven plants of *Haworthia reinwardtii* and the one of *Astroloba* sp. were all collected in the field. The plants received from Mr. Berg and Mr. Herre had been growing in botanical gardens but they were raised by gardeners who were familiar with the genera under wild conditions and who had, themselves, collected many of the plants in the field. This is a different situation from that of plants that had been shipped to Europe in perhaps the Eighteenth Century and that had been growing in bontanical gardens there for perhaps two hundred years and had gone through alternating periods of care and neglect, interest and disinterest, fashion and disrepute.

This study of the fifty plants at the Bushman's River Poort is the only really extensive one on any species of the Aloinae except the writer's (Riley 1959a) study of *Aloë Davyana* in which forty plants of one species from a highly localized area of the Transvaal were examined. Hitherto only a few

TABLE 1. *Chromosome numbers in various species of* Gasteria

| Species | No. Plants Studied | Source of Material[1] | 2n No. | Original habitat, if known | New Count |
|---|---|---|---|---|---|
| *G. acinacifolia* | 2 | H | 14 | | |
| *G. angustiarum* | 2 | H | 14 | Huisrivierbergpass, Calitzdorp | * |
| *G. Beckeri* | 8 | R | 14 | Kamtra River, Alexandria District, Cape | |
| *G. brevifolia* | 1 | H | 14 | | |
| *G. caespitosa* | 1 | B | 14 | | * |
| *G. caespitosa* | 2 | H | 14 | Somerset East | |
| *G. cheilophylla*[2] | 1 | H | 14 | | |
| *G. decipiens* | 2 | H | 14 | | * |
| *G. Ernesti-Ruschii* | 3 | H | 14 | Lorelie, Orange River, S.W. Africa | * |
| *G. gigantea*[3] | 4 | H | 14 | Port Elizabeth | * |
| *G. glabra* | 1 | H | 14 | | |
| *G. humilis* | 1 | H | 14 | Great Brak River | * |
| *G. lignosum*[3] | 2 | H | 14 | | * |
| *G. liliputana* | 1 | B | 14 | | |
| *G. liliputana* | 2 | H | 14 | | |
| *G. neliana* | 1 | H | 14 | Clanwilliam | |
| *G. neliana* | 1 | H | 14 | Steinkopf, Namaqualand | |
| *G. nigricans* | 1 | H | 14 | Algoa Bay | |
| *G. nigricans* | 2 | H | 14 | | |
| *G. poellnitziana* | 1 | H | 14 | | * |
| *G. pulchra* | 1 | B | 14 | | |
| *G. pulchra* | 3 | H | 14 | | |
| *G. retata* | 1 | H | 14 | | |
| *G. Schweicherdtiana* | 3 | H | 14 | Great Brak River | * |
| *G. Schweicherdtiana* | 1 | B | 14 | | |
| *G. subverrucosa* | 2 | H | 14 | | * |
| *G. verrucosa* | 1 | H | 14 | Mr. N. A. Smith, Oudtshoorn | |
| *G.* sp. | 1 | G | 14 | Cradock Road near Grahamstown | |
| *G.* sp. near *Zeyheri* | 50 | R | 14 | Bushman's River Poort, Alexandria District | |
| *G.* sp. | 3 | H | 14 | Mr. N. A. Smith, Oudtshoorn | |
| *G.* sp. | 1 | H | 14 | Willowmore | |
| *G.* sp. | 1 | H | 14 | Umkomas Valley, Transvaal | |
| *G.* sp. | 2 | H | 14 | Riethuis, near Kommaggas | |
| *G.* sp. | 1 | H | 14 | Calitzdorp | |
| *G.* sp. | 1 | H | 14 | Between Chalumna and Committees | |
| *G.* sp. | 1 | H | 14 | Eastern Cape | |
| *G.* sp. | 3 | H | 14 | Heidelberg, Cape, Duiwenhoeksrivier | |
| *G.* sp. | 2 | H | 14 | Klein-Amalienstein, Ladismith, Cape | |
| *G.* sp. | 1 | H | 14 | Kingwilliamstown | |
| *G.* sp. | 2 | H | 14 | Little Brak River | |
| *G.* sp. | 1 | H | 14 | Mosselbay | |
| *G.* sp. | 2 | H | 14 | Mosselbay, Gouritzriver | |
| *G.* sp. | 1 | H | 14 | Mortimer, near Cradock, Cape | |
| *G.* sp. | 1 | H | 14 | Barrydale | |
| *G.* sp. | 1 | H | 14 | Oudtshoorn | |
| *G.* sp. | 23 | H | 14 | | |

* Species marked with an asterisk are those the chromosomes of which have apparently not been counted previously.

[1] Sources of material: B, Mr. A. Berg; G, Mrs. Eily Gledhill; H, Mr. H. Herre; R, the writer.

[2] This plant is considered a hybrid by Jacobsen (1954).

[3] Not listed in Jacobsen (1954).

plants of any one species were studied and they did not pretend to represent any one particular population. Perhaps it is unfortunate that these fifty plants cannot readily be identified as to species, but actually it is not necessary to be so definite especially since they show considerable variation, enough, at least, to indicate a possible remote hybrid origin with introgressive hybridization. Time did not permit a study of the region to learn what species were growing there and how closely, and, unfortunately, the plants were not in bloom when the writer visited them. An analysis of anaphase bridges might indicate to some extent the degree of hybridization, but the plants that are growing at the University of Kentucky have not yet flowered.

TABLE 2. *Chromosome numbers in some species of* Haworthia. *All the plants studied were from whole plants either received as potted plants or dug up in the field.*

| Species | No. Plants Studied | Source of Material[1] | 2n No. | Original Habitat, if known | New Count |
|---|---|---|---|---|---|
| *H. altilinea* Haw. | 1 | B | 14 | Eastern Cape | * |
| *H. altilinea* Haw. | 1 | B | 14 | | * |
| *H. angustifolia* Haw. | 1 | B | 14 | | |
| *H. attenuata* Haw. | 1 | B | 14 | | |
| *H. cooperi* Bak. | 1 | B | 14 | | |
| *H. cymbiformis* (Haw.) Duv. | 1 | B | 14 | Eastern Cape | |
| *H. hurlingii* v. Poelln. | 1 | B | 14 | | |
| *H. Reinwardtii* (S.D.) Haw. | 7 | B | 14 | Kamtra River, Cape | |
| *H. ryderiana* v. Poelin. | 1 | B | 14 | | |
| *H. uitewaaliana* v. Poelln. | 1 | B | 14 | | * |

[1] Sources of material as listed in Table 1.

*Gasteria* probably has little more polyploidy than does *Aloë* Rosende (1950) has stated that 10.5 percent of 38 species of Gasteria are polyploid, but such a statement has little meaning. Polyploids are reported in the literature only in *G. maculata*, *G. nigricans* and *G. nigricans* var. *crassifolia*, in hybrids such as *G* × *cheilophylla* and *G. sulcata* × *G. nigricans* and in some unidentified plants growing at the John Innes Horticultural Institution. The present study adds a number of diploids but no polyploids to the list. However, further and more extensive studies in the field must be made before the true extent of polyploidy in *Gasteria* can be gauged.

Nine species of *Haworthia* were examined, mostly at the University of Pretoria, and their chromosome numbers are listed in Table 2. All were diploids, including seven plants of *H. reinwardtii*. The exact identity of this plant is a bit uncertain as it might have been one of the 19 varieties that have been described for this species. At any rate, there is no error in the specific designation. Species whose chromosomes apparently have not been recorded previously are designated by an asterisk.

The single plant of *Astroloba* (*Aprica*) that was studied was a diploid with fourteen chromosomes in the root-tip cells.

SUMMARY

1. Chromosome numbers were determined for 149 plants of the genus *Gasteria*. All were diploids. These include 50 plants resembling *G. zeyheri* (salm.) Baker from the Bushman's River Poort near Grahamstown, Cape Province, South Africa, eight of *G. beckeri* from the Kamtra River a few miles away and an unidentified plant growing along the Cradock Road northwest of Grahamstown, all of which were collected in the field.

2. Sixteen plants of *Haworthia* were diploids including seven of *H. reinwardtii* (Salm.) Haw. from the Kamtra River bank. One unidentified plant of *Astroloba* (*Apicra*) from the Great Fish River in the Eastern Cape Province was also a diploid.

Department of Botany, University of Kentucky
Department of Botany, University of Cape Town

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# SOME CHEMICAL CONSTITUENTS OF TURTLE GRASS, THALASSIA TESTUDINUM

PAUL R. BURKHOLDER, LILLIAN M. BURKHOLDER AND JUAN A. RIVERO

Primary biological productivity in the coastal waters of Puerto Rico is based upon the synthetic processes of phytoplankton, benthic algae, mangroves, corals and the turtle grass, *Thalassia testudinum*. A considerable portion of the total production of organic matter in this region appears to be contributed by the large beds of *Thalassia*, widely scattered at depths of less than five meters, over well-illuminated, shallow bays, channels, and inner margins of coral reefs. These studies have been initiated in order to find out more about the magnitude, chemical composition, and possible value of *Thalassia* to the marine life of tropical regions. Some simple comparisons of proximate analyses are made between *Thalassia*, and other primary crops of grasses from Georgia, and phytoplankton from Long Island Sound.

**Standing crop.** Determinations of the standing crop of *Thalassia* were made at representative stations near La Parguera during February of 1958. A special cutting instrument was used to obtain samples of plants including leaves, rhizomes and roots, from a uniform area of one square foot. Samples were washed in a sieve, dried in an oven at 100°C, and weighed. Typical results of the determinations are shown in Table 1. The range of

TABLE 1. *Standing crops of whole* Thalassia *plants (leaves, rhizomes, roots) in tons per acre.*

| Location | Tons per acre |
|---|---|
| West Las Palmas | 16.1–21.9 |
| East Las Palmas | 12.1–18.3 |
| East of La Parguera | 2.4– 3.1 |
| Bahia Fosforescente | 3.7– 4.9 |
| La Cueva, West | 5.8–25.7 |
| La Cueva, North | 17.6–32.9 |

eighteen determinations was calculated to be from 2.4 to 32.9 tons per acre, with an average of 12.5 tons per acre.

Estimations of the dry weight of leaves, and of rhizomes and roots, were made for seven different samples obtained at three different locations, where the bottom consisted of fine mud, mixed sand and mud, and coarse sand. Representative data are shown in Table 2. The weights of whole plants were low in regions where the mud was very fine and contained some $H_2S$. Greater total weights were observed in samples taken from sandy locations

having better aeration for the root systems. The Root Rhizome/Leaf ratio ranged, in the samples studied, from 3.0 to 7.3. It is probable that even smaller ratios occur in regions of fine mud, where the redox potential is lowered by the action of microbes on organic substrates.

**Proximate analyses.** Chemical analyses were performed on dried leaves of *Thalassia* and *Porites* from Puerto Rico, phytoplankton from Long Island Sound, and *Spartina* from the coast of Georgia, using standard methods of

TABLE 2. *Influence of bottom sediments upon the ratio of roots and rhizomes to leaves in* Thalassia.

| Location | Dry weight in grams | | |
|---|---|---|---|
| | Roots and rhizomes (RR) | Leaves (L) | $\frac{RR}{L}$ |
| Fine mud East of La Parguera | 38.5 | 12.8 | 3.0 |
| Mud and sand West Las Palmas | 378.5 | 79.7 | 4.7 |
| Coarse sand East Las Palmas | 336.5 | 46.3 | 7.3 |

the Association of Official Agricultural Chemists. Proximate analyses were performed on the turtle grass, coral and phytoplankton by Food and Drug Research Laboratories, Maspeth 78, New York City. Results of the proximate analyses for *Thalassia* and other materials are shown in Table 3. Data

TABLE 3. *Proximate analysis of* Thalassia *leaves,* Porites, *phytoplankton,* Spartina *leaves and Coastal Bermuda grass leaves. All data are given in per cent dry weight, except the caloric values.*

| *Determinations* | *Materials* | | | | |
|---|---|---|---|---|---|
| | *Thalassia* leaves | *Porites* coral | Plankton L.I.S. | *Spartina* leaves | Bermuda grass |
| Protein (N × 6.25) | 13.1 | 3.4 | 14.6 | 9.8 | 13.1 |
| Fat | 0.5 | 1.4 | 3.7 | 2.4 | 2.0 |
| Ash | 24.8 | 90.4 | 59.5 | 11.5 | 4.6 |
| Crude fibre | 16.4 | 1.5 | 1.6 | 31.0 | 33.0 |
| Other carbohydrate | 35.6 | 1.9 | 15.6 | 45.3 | 47.3 |
| Calories/100 grams | 199 | 23 | 154 | 375 | ..... |

for *Spartina* and Bermuda grass are taken from earlier work (Burkholder 1956). The results indicate that protein content of *Thalassia* is about equal to that of phytoplankton, and Coastal Bermuda grass. The fat content is comparatively low, crude fiber intermediate in amount, and other carbohydrate fairly high. Oxidizable matter in *Thalassia*, as is indicated by the caloric value, lies between that of phytoplankton and *Spartina* leaves. The total ash content of *Porites* was extremely high, with silica esimated at about

17 per cent. The phytoplankton also assayed in ash content much higher than the phanerogamic plants.

**Amino acids.** Quantitative determination of aspartic and glutamic acids and ten essential amino acids was performed by one of us (L.M.B.), using the microbiological methods and materials provided by H.M. Chemical Company, 1754—22nd St., Santa Monica, Calif. (1957). In preparation for assay of all amino acids, except tryptophan, materials were hydrolyzed by refluxing in HCl solution. Hydrolysis with NaOH in the autoclave was employed for release of tryptophan. The assay organisms were *Lactobacillus casei*, *L. arabinosus* 8014, and *L. mesenteroides* 8042, all obtained from American Type Culture Collection, Washington, D.C. All assays were readily performed, but somewhat greater difficulty was encountered in obtaining satisfactory growth in the determinations of tryptophan, lysine, methionine and phenylalanine.

The data for 12 amino acids of *Thallasia* are presented, along with comparable data, obtained earlier (Burkholder 1956), for 10 amino acids of *Spartina,* in Table 4. The two most abundant amino acids determined for

TABLE 4. *Amino acid constituents of the leaves of* Thalassia testudinum *expressed in per cent (gm. amino acid per 100 gm. of dried material). For comparison, typical data obtained for leaves of* Spartina alterniflora *are also given.*

| Amino acids | *Thalassia* % of dry matter | *Spartina* % of dry matter |
|---|---|---|
| Arginine | 0.702 | 0.182 |
| Aspartic acid | 1.120 | no assay |
| Glutamic acid | 1.090 | no assay |
| Histidine | 0.310 | 0.028 |
| Isoleucine | 0.249 | 0.143 |
| Leucine | 0.693 | 0.214 |
| Lysine | 0.720 | 0.769 |
| Methionine | 0.187 | 0.038 |
| Phenylalanine | 0.465 | 0.128 |
| Threonine | 0.204 | 0.256 |
| Tryptophan | 0.049 | 0.086 |
| Valine | 0.317 | 0.149 |

*Thalassia* are aspartic and glutamic acids, occurring just above the 1 per cent level, with arginine, leucine and lysine, each occupying about 0.7 per cent of the dry weight. Among the 12 amino acids, the lowest value was found for tryptophan, at 0.049 per cent. In comparing data of *Thalassia* with earlier results obtained for *Spartina,* higher values for such compounds as arginine, histidine, and methionine in turtle grass, suggest a better biological value of the proteins of *Thalassia* than of *Spartina* for the nutrition of fishes. The tryptophan content of *Thalassia,* however, is lower than that in *Spartina;* therefore, this amino acid may represent a weak nutritive element in the direct use of Thalassia proteins by fish life in tropical waters.

**Bacteria and Thalassia.** The quantitative distribution of marine bacteria,

adjacent to and in beds of *Thalassia*, was studied in a channel lying between Magueyes Island and the mainland near La Parguera. Samples of water and grass were collected in bottles, and dilution-pour-plates were prepared in Difco nutrient agar made with sea water. The number of colonies that developed aerobically after 48 hours was taken to indicate the quantitative occurrence of bacteria in different samples. Typical results, shown in Table 5,

TABLE 5. *Quantitative estimates of the aerobic bacteria present in the environment of* Thalassia *at Magueyes Island, Puerto Rico.*

| *Source of Samples* | *Bacteria per ml. or gm. of Sample* |
|---|---|
| 1. Surface water outside *Thalassia* | 627 |
| 2. Surface water above *Thalassia* | 600 |
| 3. Water in bed of *Thalassia* | 3,968 |
| 4. Water from agitated *Thalassia* | 192,000 |
| 5. Mud from bed of *Thalassia* | 3,700,000 |
| 6. *Thalassia* ground in mortar | 15,104,000 |

indicate that comparatively large numbers of bacteria are present in the mud and on the leaves of *Thalassia*. Mechanical disturbance of the plants in their natural habitat (Sample 4) resulted in substantial increase of the bacteria in the surrounding water. The number of bacteria released by grinding a gram of leaf material (Sample 6) was considerably higher than that recovered from a gram of sediment (Sample 5).

In order to gain some information about the nutritional responses of the bacteria of grass meadows, a mixed population of the microorganisms present in mud and on grass leaves was inoculated into six different media. The basal medium consisted of mud extract, which was prepared by boiling 500 gm. of marine sediment in a liter of sea water, followed by paper filtration. Five other media were then prepared by adding to the mud extract (medium 1) different materials as follows: N-Z case 1% (medium 2); *Thalassia* leaves 10 gm. per 100 ml. (medium 3); dextrose 0.25% (medium 4); $KH_2PO_4$ 0.002% + $NH_4NO_3$ 0.05% (medium 5); dextrose 0.25% + $KH_2PO_4$ 0.002% + $NH_4NO_3$ 0.05% (medium 6). After incubation at 28°C for 24 hours, the turbidity of growth was measured in a Bausch and Lomb colorimeter. Per cent light absorption in the different media was observed as follows: (Medium 1) 3%; (2) 98%; (3) 90%; (4) 31%; (5) 8%; (6) 37%. It may be concluded that, although dextrose promotes growth of the mixed population of microbes in the mud-extract medium, addition of amino acids from casein hydrolysate or turtle grass greatly stimulates growth. Mud extract by itself was not adequate for microbial growth. These data are in agreement with other studies on growth of bacteria taken from sediments of Long Island Sound and from Sapelo Island, Georgia.

Thirty-five bacterial isolates, obtained by plating marine mud and water from the region of La Parguera, were tested for their ability to grow in sea

water containing soluble material extracted from *Thalassia*. With methods of preparing extracts set forth in an earlier paper (Burkholder and Bornside 1957), 4.1 mg. of dry extractives were incorporated into each milliliter of medium. Among the 35 isolates tested, 10 grew very well, 18 made fair growth, and 7 failed to show any growth.

Four of the cultures which grew well on grass extract medium were grown again for 24 hours in sea water *Thalassia* leaf extract broth, containing 9.7 mg. of grass solubles per ml. The bacteria were then separated on millipore filters, dried and weighed. Calculations show that these bacteria grown on the organic extract from *Thalassia* leaves added to sea water medium, were able to convert from 14 to 23 per cent of the extractives to bacterial dry matter. This compares closely with calculations which have been made for bacteria growing on extracts of *Spartina* (Burkholder and Bornside 1957). It is of considerable interest to note that the amino acids found most abundantly in the proteins of *Thalassia*, e.g., aspartic acid and glutamic acid, are best utilized by common marine bacteria.

Microscopic studies on microbial decomposition of non-sterile, macerated *Thalassia* leaves indicated that very large populations of bacteria rapidly developed, and that these, in all experiments with mixed cultures, were promptly followed by tremendous growths of ciliated protozoa. It seems probable that many predatory animals, which live in the meadows of turtle grass, may be feeding upon microbial populations of bacteria, ciliates, and other transformers, which are supported by chemical constituents of *Thalassia*. Studies on the stomach contents of balahoo fishes, *Hemiramphus brasiliensis*, showed their main food to be leaves of *Thalassia*, and some plankton. It seems probable, however, that the greatest use of the primary production of turtle grass is mediated through microbial conversions of organic matter in the leaves, rhizomes and roots.

## SUMMARY

1. Turtle grass, *Thalassia testudinum*, is abundant in the shallow well-illuminated waters of Puerto Rico and other tropical areas. The standing crop of *Thalassia*, ranging up to about 33 tons per acre, provides shelter for many species of animals, and contains large amounts of basic foodstuffs, in the form of proteins 13%, crude fiber 16%, and other carbohydrates 36%.

2. Among the 12 amino acids assayed, the most abundant were aspartic and glutamic acids, arginine, lysine and leucine. Tryptophan was relatively scarce.

3. Marine bacteria convert organic constituents of *Thalassia* to microparticulate food suitable for protozoa, which are in turn available to smaller and larger animals.

4. Some fishes, notably the ballahoo, may feed almost exclusively on leaves of *Thalassia* at certain times.

5. Much work remains to be done on the ecology of *Thalassia* and its contribution in the cycle of productivity through intermediary conversion by bacteria and protozoa.

Brooklyn Botanic Garden
Brooklyn, New York,
Institute of Marine Biology,
University of Puerto Rico

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# PHYLOGENETIC RELATIONSHIPS OF TWENTY-ONE SPECIES OF LOBELIA L. SECTION LOBELIA[1]

WRAY M. BOWDEN

McVaugh (1936) based his discussion of the relationships of the species of *Lobelia L.* section Lobelia on morphological characteristics and geographical distribution. I was much interested in McVaugh's distributional maps and considered that this group of species would be an ideal one for cytotaxonomic and cytogenetic investigations. During the past eighteen years, I have made detailed taxonomic, ecological, cytological, and genetic studies on section *Lobelia*. The data now available have resulted in a new analysis of the phylogenetic relationships of twenty-one species.

Preliminary results of these studies were reported by Bowden (1948a, 1948b, 1958). In the present paper, the results of the studies on taxonomy, ecology, cytology, and genetics are summarized in order to provide a sound basis for discussing the phylogenetic relationships (fig. 1). Detailed data will be reported in later papers, including citation of voucher specimens.

**Methods and materials.** Seeds, plants, and dried specimens of these twenty-one species of *Lobelia* were collected on field trips in southern Ontario, on an extensive field trip from Ontario to Florida in 1954, and by means of an active correspondence with American and Canadian botanists and a Swedish botanist. Plants of all the taxa mentioned in the present paper were grown in experimental plots and greenhouses during this eighteen-year period. Seeds of *L. dortmanna*, an aquatic species, were germinated in water. For the other twenty species, germination of fresh seeds or seeds as old as five years, was obtained by sowing the seeds on the surface of moist soil. Only the seeds of *L. kalmii* required cold-treatment. At least some of these species have light-sensitive seeds. Muenscher (1936) demonstrated the light-sensitivity of seeds of three species: *L. inflata, L. cardinalis,* and *L. siphilitica*. However, Muenscher observed that seeds of *L. dormanna* germinated in both light and darkness.

Somatic and meiotic chromosome numbers were determined and these data have been recorded on voucher specimens in the Divisional Herbarium (DAO). Numerous artificial interspecific and intervarietal hybrids were grown and studies made on their fertility or sterility and their meiotic chromosome behaviour.

**Taxonomy.** McVaugh (1936, 1943) made detailed studies on the taxonomy and geographical distribution of the North American species of

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*Lobelia*. Wimmer (1953, 1956) monographed the subfamily *Lobelioideae* and made some taxonomic revisions in *Lobelia* section *Lobelia*.

McVaugh (1936) concluded that "the North American Lobelias form a distinct unit, clearly separable from geographically neighbouring ones." The twenty-one North American species of section *Lobelia* that I recognize are native in the area from mid-Canada to Panama. One northern species, *L. dortmanna*, occurs across mid-North America and in northwestern Europe. *Lobelia kalmii* is a northern species and *L. inflata* is found in eastern North America. Eighteen other species have an area of greatest diversification and a center of speciation in the southeastern United States. Three of these eighteen species occur in Canada, namely, *L. siphilitica, L. spicata* and *L. cardinalis. Lobelia cardinalis* ranges from eastern Canada to Panama and shows a much greater range of morphological and genetic variation in the southern part of the area, from the southern United States, Mexico and Panama.

McVaugh (1943) included the North American species of *Lobelia* in section *Dortmanna*. In this section, he also included *L. rotundifolia* Juss., a shrubby species from Hispaniola and Puerto Rico; see also McVaugh (1952). I do not consider that *L. rotundifolia* belongs with the North American species in section *Lobelia*, but rather that it is related to some of the shrubby species. Wimmer (1953) included *L. rotundifolia* and other shrubby species in section *Eutupa* and included the North American species of *Lobelia* that are discussed in the present paper in section *Hemipogon*, subsection *Trachyspermae*.

The type species of *Lobelia* L. is *L. dortmanna* L. It was selected as the type species by Britton and Brown (1913) and accepted as type by McVaugh (1943). Article 22 of the Code, Lanjouw *et al.* (1956), now provides that the section that includes the type species of a genus should be called by the same name as the genus. Consequently, the sectional name for the North American species under consideration is section *Lobelia*. It should be noted that several other species of *Lobelia* belonging to other sections also occur in the southern United States. Species such as *L. laxiflora* and *L. berlandieri* are allied to species in other sections that are native in Mexico and southern regions; these species are not considered in this paper.

During this investigation, many herbarium specimens have been examined and types, or photographs of types, or authentic specimens of all taxa have been examined. Numerous specimens annotated by Dr. McVaugh have been available for study.

**Nomenclature.** I am using ten specific names in the same sense as McVaugh (1936, 1943) and Wimmer (1953). The names of these species are: *L. inflata* L., *L. feayana* A. Gray, *L. nuttallii* R. & S., *L. canbyi* A. Gray, *L. boykinii* T. & G., *L. glandulosa* Walt., *L. floridana* Chapman, *L. paludosa* Nutt., *L. brevifolia* Nutt., and *L. elongata* Small.

In *L. siphilitica* L., I recognize only var. *siphilitica* and var. *ludoviciana* A. DC. as listed by McVaugh (1943). I do not recognize any distinct varieties in *L. kalmii* L. or in *L. dormanna* L. and use these two names in the same sense as McVaugh (1936, 1943). *Lobelia flaccidifolia* Small includes *L. halei* Small in the sense of McVaugh (1943) and Wimmer (1953).

McVaugh (1936) recognized *L. glandulifera* (Gray) Small (not the earlier *L. glandulifera* Kuntze), and later (1940) proposed a new name for the taxon: *L. georgiana* McVaugh. McVaugh (1943) recognized it as a variety, *L. amoena* Mx. var. *glandulifera* A. Gray. I use the name *L. georgiana* McVaugh for this species as did Wimmer (1953).

McVaugh (1936) and Wimmer (1953) recognized *L. amoena* Mx. For this taxon, McVaugh (1943) used the name, *L. amoena* Mx. var. *amoena.* He listed two questionable synonyms: "?*Lobelia colorata* Sweet" (*non L. colorata* Wall.) and "?*Lobelia hortensis* A. DC." I consider that both of these names are *nomina dubia* since the descriptions are not sufficient to accurately identify the plant on which the names are based and the original specimen cannot be located.

I have examined a photograph and some fragments (DAO) of the holotype of *L. georgiana* McVaugh var. *azurea* Wimmer that was described by Wimmer (1953) and have identified the specimen as belonging to *L. elongata* Small. There are teeth on the calyx-lobes of the holotype of var. *azurea* but a few other specimens of *L. elongata* also have teeth on the calyx-lobes.

McVaugh (1936, 1943) and Wimmer (1953) recognized five varieties of *L. spicata* Lam. I recognize four varieties: var. *spicata,* var. *hirtella* A. Gray, var. *leptostachys* (A. DC.) Mackenzie & Bush and var. *scaposa* McVaugh. I do not recognize var. *campanulata* McVaugh as a distinct variety and place it under *L. spicata* Lam. var. *spicata.* Since the plants with white-colored anthers do differ from the type of var. *spicata,* I am reducing this taxon to a form and call it:

**Lobelia spicata** Lam. var. **spicata** f. **campanulata** (McVaugh) stat. nov., based on *L. spicata* Lam. var. *campanulata* McVaugh, Rhodora 38: 316. 1936.

The anthers of plants of f. *campanulata* are white and are pollen-sterile. Plants of f. *campanulata* can set seed by cross-pollination with normal plants. This phenomenon shows a tendency towards dioecism. I have also noticed the same tendency in occasional plants of *L. siphilitica* L., *L. brevifolia* Nutt., and *L. elongata* Small. Self-sterile plants with white anthers are more common in *L. spicata* populations and I have noticed such plants in both var. *spicata* and var. *hirtella.*

McVaugh (1936) and Wimmer (1953) recognized *L. appendiculata* A. DC. and *L. gattingeri* A. Gray, but McVaugh (1943) reduced the latter to a variety, *L. appendiculata* A. DC. var. *gattingeri* (A. Gray) McVaugh. I agree with McVaugh (1936) that *L. gattingeri* shows a strong relationship

to *L. appendiculata*. Specimens of *L. gattingeri* have distinctive morphological characteristics and I regard the taxon as a species.

McVaugh (1943) recognized two subspecies of *L. cardinalis* L., namely, subsp. *cardinalis* and subsp. *graminea* (Lam.) McVaugh. He listed four varieties of subsp. *graminea* and I recognize three of them: var. *graminea*, var. *pseudosplendens* McVaugh and var. *phyllostachya* (Engelm.) McVaugh. The fourth variety, var. *multiflora* (Paxton) McVaugh, needs to be considered further before I can accept the name or the taxon although I have grown plants with short-pubescent stems that McVaugh would have included in this variety. Wimmer (1953) recognized four species and numerous varieties in this complex of plants with red corollas; I plan to give a revised taxonomic treatment in a later paper. I consider that all these taxa belong to one species complex, *L. cardinalis*.

Under *L. puberula* Mx., McVaugh (1936) listed four "pronounced geographical forms which may or may not be worthy of varietal names." He also recognized a fifth taxon, *L. puberula* var. *pauciflora* Bush. McVaugh (1943) listed as synonyms the varietal names that had been used for variants of *Lobelia puberula* Mx. and thought that *L. puberula* var. *pauciflora* "may deserve recognition." Fernald (1947) recognized five varieties: the typical variety now called var. *puberula*; var. *simulans* Fern.; var. *obtusifolia* (A. DC.) Fern.; var. *mineolana* Wimmer; and presumably he meant to include var. *pauciflora* Bush. Wimmer (1953) recognized four varieties: var. *puberula* (incl. var. *simulans* Fern.); var. *mineolana;* var. *pauciflora;* and var. *obtusifolia*.

Wimmer (1953) thought that the New York Botanical Garden specimen of *Palmer 8905* was *L. puberula* var. *pauciflora* but that *Palmer 8905* in the Kew Herbarium was morphologically different and he recognized the latter as a new species, *L. vaughiana* Wimmer. I have examined three specimens of *Palmer 8905* (NY, US and K) and was unable to see much difference between the three specimens. The Kew specimen was very similar to the specimen in the United States National Museum. The specimen at New York, which was listed by McVaugh (1936) as *L. puberula* var. *pauciflora* Bush, is similar but differs in the less dentate leaf margins. Turner (1950) considered that the taxon known as *L. puberula* var. *pauciflora* was very distinct from *L. puberula* and he raised it to specific status as *L. reverchonii* Turner. Since it is undoubtedly closely related to *L. puberula* but does have distinctive characteristics and a very small geographical range in eastern Texas and western Louisiana, I consider that it should be a subspecies and call it:

**Lobelia puberula** Mx. subsp. **pauciflora** (Bush) stat. nov., based on *L. puberula* Mx. var. *pauciflora* Bush, Ann. Rep. Mo. Bot. Gard. 17: 122. 1906. *L. reverchoni* Turner, Field & Lab. 18: 47. 1950. *L. vaughiana* Wimmer, Pflanzenr. IV, 276b (107. Heft.): 425. fig. 76h. 1953.

I agree with Wimmer (1953) that *L. puberula* Mx. var. *simulans* Fern. is not sufficiently distinct geographically and morphologically to justify recognition as a variety. I call it:

**Lobelia puberula** Mx. subsp. **puberula** var. **puberula** f. **simulans** (Fern.) stat. nov., based on *Lobelia puberula* Mx. var. *simulans* Fern., Rhodora 49: 184. 1947. It is form (a) of McVaugh (1936).

Form (b) of McVaugh (1936) is *L. puberula* Mx. var. *puberula;* form (c) is var. *obtusifolia* (A. DC.) Fern. and form (d) of McVaugh (1936) is var. *mineolana* Wimmer.

**Ecology.** Most of the species of section *Lobelia* grow in moist habitats such as ditches, marshes, along the edges of streams and woods or in thinly-wooded areas. Some species can tolerate much drier soil conditions than other species; for example, populations of *L. spicata* or *L. siphilitica* are sometimes encountered in habitats such as open fields where the soil is not saturated with water. Many of the other species often occur in areas where the soil is saturated with water. Plants of some species of section *Lobelia* thrive in such wet places, for example, *L. cardinalis* and *L. floridana*. Sometimes the stem bases are immersed in water and plants of *L. cardinalis* have been observed in habitats where either fresh or stagnant water covered the bases of the plants. The only truly submerged aquatic species in section *Lobelia* is *L. dortmanna*. Normally, plants of this species are completely submerged except that the racemes are above the water.

The geographical ranges of the taxa listed in the present paper have been given in detail by McVaugh (1936, 1943) and Wimmer (1953). Some range extensions have been noted and will be recorded in later papers.

I have studied the life duration of living plants of the twenty-one species of section *Lobelia*. All populations, except those of *L. inflata*, were potentially short-lived perennials. When the racemes of these twenty species matured, small secondary vegetative rosettes were usually produced at the bases of the stems near the soil line. McVaugh (1936, 1943) gave several notes on life duration but the new information in the present paper is significant because it indicates that twenty of the species of section *Lobelia* have a fundamental genetic characteristic in their ability to produce basal rosettes. These vegetative rosettes can produce racemes during the next season. Individual plants do not usually seem to persist for many years under field conditions and for that reason I call them short-lived perennials. In the field, occasional clumps of a few species, for example, *L. cardinalis* and *L. floridana,* have been observed; these clumps were large and appeared at least three or four years old. Under cultivation, clones of some species and some interspecific hybrids can be vegetatively propagated and grown as long-lived perennials. The first-year seedlings (germinated in the greenhouse) of all except *L. kalmii* and *L. cardinalis* subsp. *cardinalis* bloomed during the first year without cold-treatment. A few plants of subsp. *cardi-*

*nalis* bloomed during the first year but usually only primary vegetative rosettes were formed. Seedlings of *L. dortmanna* were not grown to maturity but wild plants were successfully grown in a tank containing water (partly cold-treated). In the greenhouse, plants of all species thrived in John Innes potting mixture, except that for *L. kalmii*, ground limestone was added to the soil and the plants required cold-treatment to produce normal growth.

Plants of *L. inflata* have a different length of life duration from the other twenty species of section *Lobelia*. For several years, field populations of *L. inflata* were studied by the author just south of Ottawa. A series of specimens have been preserved to show that, in the Ottawa area, the plants are mostly biennial and probably some of the wild plants are annual. In September, populations of *L. inflata* consisted of mature plants of various sizes with ripe capsules or flowers and numerous plants that were new primary seedling rosettes that would produce racemes during the next season. I sowed fresh ripe seed in experimental plots in autumn and there was almost no germination until May of the following year when a very high percentage of germination was obtained. Many of the plants under cultivation bloomed during August of the year of germination but there were numerous primary seedling rosettes that remained vegetative during the first season. In the greenhouse, fresh seed germinated in autumn although the seed had not been cold-treated.

Field plants of *L. inflata* always matured and died without formation of secondary basal rosettes. Seedlings of *L. inflata* were grown in the greenhouse without cold-treatment; some of the seedlings produced racemes but others remained sterile and formed large vegetative primary rosettes. There was an unusual formation of secondary basal rosettes in some of these greenhouse plants. Thus, plants of *L. inflata*, a species that is ordinarily biennial or annual, show a trace of the ability to produce secondary basal rosettes though this tendency is not nearly as pronounced as in the other twenty species of section *Lobelia*. In areas warmer than Ottawa, particularly in the southern part of the species range of *L. inflata*, it is possible that plants of this species behave as winter annuals.

Plants of *L. feayana* can produce vegetative rosettes. As long as the plants grow under favorable conditions, they can continue to produce basal rosettes or new stems from the lower leaf axils of the procumbent stems. Usually the habitat becomes too dry and the plants of *L. feayana* die after a period of growth and development during which seed is abundantly produced. The soil can become saturated with seed that may germinate when favorable conditions for growth reoccur.

**Chromosome numbers.** Fifteen species were diploid ($2n = 14$): *L. dortmanna*, *L. kalmii*, *L. inflata*, *L. feayana*, *L. canbyi*, *L. boykinii*, *L. gattingeri*, *L. appendiculata*, *L. spicata*, *L. flaccidifolia*, *L. brevifolia*, *L. georgiana*, *L. puberula*, *L. siphilitica*, and *L. cardinalis*. One species, *L. nuttallii*, had both

diploid ($2n = 14$) and tetraploid ($2n = 28$) plants. Three species were tetraploid ($2n = 28$): *L. glandulosa, L. elongata* and *L. amoena*. Two species were hexaploid ($2n = 42$): *L. floridana* and *L. paludosa*.

In some of the diploids, for example, *L. dortmanna, L. kalmii, L. inflata* and *L. georgiana*, the chromosome number of all plants examined was $2n = 14$. In some tetraploid species, for example, *L. amoena*, the somatic chromosome number was always $2n = 28$. Small supernumerary chromosomes were encountered in some plants of some of the other species and were observed, for example, in *L. cardinalis, L. puberula, L. elongata*, and *L. glandulosa*. Either one or two or rarely from three to five supernumeraries were counted. The supernumeraries were always smaller than the normal chromosomes and were always the same relative size or sizes and numbers in all the cells examined of a particular plant. An account of the occurrence or absence of supernumeraries will be given in later papers.

In section *Lobelia*, a study of the relationship between chromosome number and geographical distribution yields some definite conclusions. If the maps of McVaugh (1936) are studied with the chromosome numbers given above it is apparent that the ranges of the diploids vary from very large to very small. All of the widespread species of section *Lobelia* are diploids: *L. cardinalis, L. siphilitica, L. puberula, L. inflata* and *L. spicata*. The two transcontinental species, *L. kalmii*, and *L. dortmanna*, the latter also occurring in northwestern Europe, are also diploid species. Of the remaining diploids, *L. nuttallii* (diploid in part) and *L. georgiana* occupy smaller geographical areas. The diploid plants of *L. nuttallii* were collected in New Jersey, Virginia and North Carolina, and the tetraploids occurred in North and South Carolina. The other diploids have even smaller geographical ranges: *L. feayana, L. flaccidifolia, L. appendiculata, L. gattingeri, L. brevifolia, L. canbyi*, and *L. boykinii*.

The three tetraploids occupy relatively small areas compared with some of the widespread diploids. *Lobelia glandulosa* has the largest range of the tetraploids; *L. elongata* is restricted to areas near the coast; and *L. amoena* is found in the southern Appalachians from western North Carolina to eastern Alabama. The two hexaploids, *L. floridana* and *L. paludosa*, are restricted to areas in Florida and adjacent states.

**Hybridization.** McVaugh (1943) listed two natural interspecific hybrids in section *Lobelia*. Wimmer (1953) listed several new hybrids and Bowden (1948a) listed some artificial interspecific hybrids in section *Lobelia*.

There is considerable doubt about some of the hybrid formulae listed by Wimmer (1953). When he published the name *L. vaughiana*, which I regard as a synonym of *L. puberula* subsp. *pauciflora*, he wrote the formula: "?*L. puberula* × *L. syphilitica* var. *ludoviciana*." I have grown some artificial hybrids of the parentage, *L. siphilitica* var. *ludoviciana* × *L. puberula* var. *puberula;* the hybrids are morphologically different from *L. puberula* subsp.

*pauciflora*. I do not consider that the latter taxon is a hybrid of the parentage listed by Wimmer.

Wimmer (1953) wrote the formula, *L. georgiana* × *L. amoena*, for the specimen of *Jewett 53* collected at Mobile, Alabama. Two sheets of this collection from the Goettingen Herbarium, were examined by the present author and in my opinion both specimens are the hybrid, *L. brevifolia* × *L. puberula*. Wimmer's formula does not apply to these two specimens on the grounds of the morphology of the specimens, the geographical ranges of the supposed parents and the locality where Jewett's specimen was collected. I attempted to cross *L. georgiana* and *L. amoena* but was unable to produce hybrids.

Wimmer (1953) wrote: "*L. amoena* × *L. puberula* = *L. colorata* Sweet." The identity of *L. colorata* Sweet is questionable and the name has already caused confusion in several papers. Attempts were made to cross *L. amoena* and *L. puberula* but no hybrids could be produced. I do not think that the formula suggested by Wimmer can be assigned to *L. colorata* Sweet.

Wimmer also listed "*L. amoena* × *L. puberula* = *L. azurea* Hort." Dr. Graham's specimen from the Delessert Herbarium was examined on loan and in my opinion the specimen is not a hybrid of the parentage suggested; I have identified the specimen as *L. amoena* Mx.

In the present paper, a few of the formulae of hybrids listed by Bowden (1948a) are revised. The name for the hybrid, *L. siphilitica* × *L. cardinalis*, is *L.* × *speciosa* Sweet. Since 1948, many artificial diploid and tetraploid nothomorphs representing many different combinations of the infraspecific taxa of these two species have been grown in the Dominion Arboretum.

Artificial interspecific hybrids of the following parentages have been grown:

*L. siphilitica* × *L. puberula*;
*L. siphilitica* × *L. georgiana*;
*L. siphilitica* × *L. brevifolia*;
*L. puberula* × *L. georgiana*;
*L. brevifolia* × *L. puberula*;
*L. georgiana* × *L. brevifolia*;
*L. georgiana* × *L. glandulosa*;
*L. paludosa* × *L. floridana*;
*L. amoena* × *L. elongata*;
*L. glandulosa* × *L. elongata*;
*L. amoena* × *L. glandulosa*;
*L. amoena* × *L.* × *speciosa*;
*L. glandulosa* × *L.* × *speciosa*;
*L. elongata* × *L.* × *speciosa*;
*L. flaccidifolia* × *L. puberula*;
*L. puberula* × *L. feayana*;
*L. flaccidifolia* × *L. feayana*;
*L. puberula* × *L. appendiculata*;
*L. canbyi* × *L. nuttallii* (diploid);
*L. canbyi* × *L. gattingeri*;
*L. gattingeri* × *L. feayana*;
*L. appendiculata* × *L. gattingeri*

Complex hybrids were also grown that involved crosses between tetraploid hybrids of *L. cardinalis*, *L. siphilitica*, *L. puberula*, *L. amoena*, *L. glandulosa*, and *L. elongata*.

This list of hybrids does not necessarily represent all of the artificial hybrids that could be produced. The list may give the impression that these interspecific hybrids are easily produced. However, field studies indicate that interspecific hybrids of section *Lobelia* occur rarely in natural habitats. There are strong sterility barriers between many species under natural field conditions. Some of the species cannot be hybridized, or they flower at different times, occupy different ecological habitats or different geographical ranges. Many species probably cannot be hybridized and interspecific hybrids could not be produced from many cross-pollination attempts.

At the diploid level, *L. cardinalis* could only be crossed with *L. siphilitica*. At the tetraploid level, complex artificial hybrids were produced that involved *L. cardinalis* and as many as three other species.

McVaugh (1936) observed specimens intermediate between the named varieties in some species complexes. I was able to obtain numerous artificial intervarietal or intersubspecific hybrids within the following species: *L. cardinalis; L. siphilitica; L. puberula;* and a few varietal hybrids in *L. spicata*. Plants of each of the twenty-one species of section *Lobelia* were normally cross-pollinated but when tested, many plants of these species were self-fertile.

Sterility and fertility and meiotic chromosome behaviour in the hybrids were studied and these data have been very helpful in assessing relationships of the taxa. Since the data are too voluminous to include in the present paper, they will be cited in a later paper.

**Phylogenetic relationships.** A diagram (fig. 1) has been prepared to illustrate my conclusions on the relationships of the twenty-one species of section *Lobelia*. This diagram can be interpreted more easily if it is examined together with the distributional maps of McVaugh (1936) and with specimens annotated by Dr. McVaugh that are available in many North American herbaria. The excellent drawings of fourteen species of *Lobelia* in Gleason (1952) show some of the distinctive morphological characteristics. In Gleason's drawing of *L. boykinii*, the raceme and single flower belong to that species, but the lower stem and the raceme with capsules (on the left) belong to *L. inflata*.

The earliest populations of *Lobelia* in eastern North America were probably established "in Tertiary times or before" as suggested by McVaugh (1936). The continent was lower than it is now and the present Coastal Plain was largely submerged. When the Appalachian Mountain system was uplifted, the present Coastal Plain emerged and was available for occupancy by plant populations that spread from the older areas. These older areas included the inland continental Appalachian region and miscellaneous Coastal-

Plain areas. During the Pleistocene, the northern species survived south of the glaciers and re-invaded the glaciated area in post-glacial times.

All the species of section Lobelia have evolved from diploid ($2n = 14$) an-

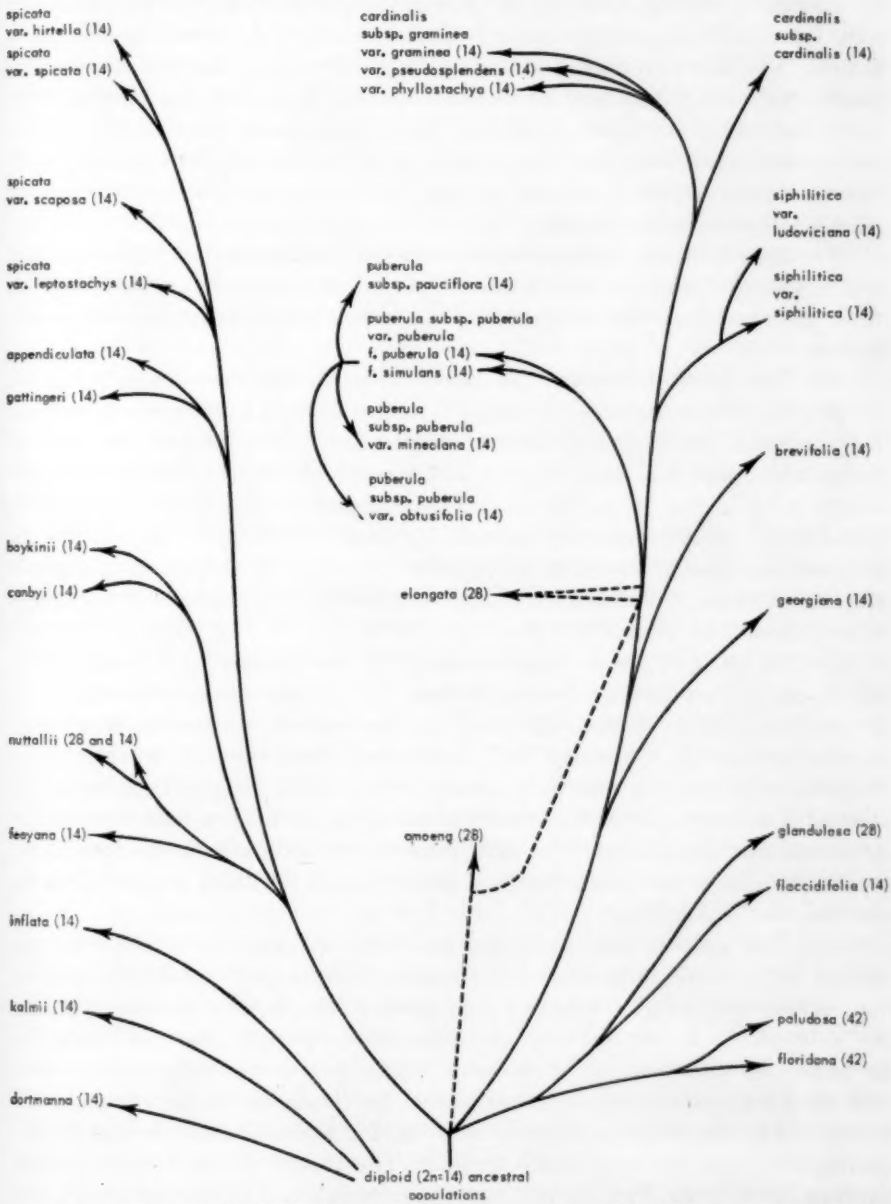


FIG. 1. Theoretical relationships of twenty-one species of *Lobelia* L. section *Lobelia*. Somatic chromosome numbers ($2n$) are shown in parentheses.

cestral populations. Four distinct lines of speciation can be traced.

In each of three lines, only a single diploid species has survived: *L. dortmanna*, *L. kalmii*, and *L. inflata*. In the northern part of the area occupied by species of section *Lobelia*, two northern species have survived and are now found in both glaciated and unglaciated areas: *L. kalmii* and *L. dortmanna*. The latter species also occurs in northwestern Europe. In eastern North America, the annual or biennial species, *L. inflata*, occupies a large area. Each of these three diploid species is morphologically distinct from one another and from the other species of section *Lobelia* and appear to be old segregate species from the ancestral populations. These three species have small flowers (7–22 mm.).

The fourth line is a more complex branch that has evolved three rather distinct subgroups: (i) seven small-flowered species; (ii) a subgroup of four narrow-leaved species; and (iii) seven medium-to large-flowered species.

(i) **The small-flowered species.**—These species have small flowers (7–15 mm.). The subgroup includes six diploid species, *L. feayana*, *L. canbyi*, *L. boykinii*, *L. gattingeri*, *L. appendiculata*, and *L. spicata*, and one species, *L. nuttallii*, that has both diploid and tetraploid plants. *Lobelia nuttallii* occurs both in the Appalachian Mountains and on the Coastal Plain. It seems to be an old segregate species. McVaugh (1936) considered that *L. feayana* was closely related to *L. nuttallii*. However, *L. feayana* has distinctive morphological characteristics and a different geographical range since it occurs only in peninsular Florida.

*Lobelia nuttallii* shows relationship to *L. canbyi* and to *L. boykinii* in the small, narrow, cauline leaves. *Lobelia canbyi* also shows relationship to *L. gattingeri*, *Lobelia gattingeri* and *L. appendiculata* are closely related to one another as shown by leaf morphology and ease of hybridization. *Lobelia gattingeri* is a segregate species with a small geographical range in central Tennessee. *Lobelia appendiculata* seems to be the nearest relative of *L. spicata*. *Lobelia spicata*, with four varieties, has been the most successful species of the small-flowered group and it occupies a large area in eastern North America.

(ii) **The narrow-leaved subgroup.**—This subgroup of narrow-leaved species with small- to medium-sized flowers (11–33 mm.) and with pubescent lower-corolla lips consists of four species: the diploid, *L. flaccidifolia;* the tetraploid, *L. glandulosa*; and two hexaploids, *L. floridana* and *L. paludosa*. *Lobelia glandulosa* probably originated by hybridization of narrow-leaved ancestral plants, accompanied by doubling of the chromosome number. The two hexaploids are closely related to one another but are morphologically and geographically distinct. The ranges of these four species overlap in western Florida but each species has a different geographical range.

(iii) **The medium- to large-flowered species.**—The remaining seven species have larger flowers (15–50 mm.). Five species of this subgroup were diploid: *L. georgiana, L. brevifolia, L. puberula, L. siphilitica,* and *L. cardinalis;* and two species were tetraploid: *L. elongata,* and *L. amoena.*

In the medium to large-flowered subgroup, there appear to be three diploid species that were segregated rather early: *L. brevifolia, L. georgiana,* and *L. puberula. Lobelia brevifolia* has a very restricted range along the northern coast of the Gulf of Mexico from western Florida to eastern Louisiana. *Lobelia georgiana* has a much wider distribution and occurs from Florida to Virginia. However, the most successful of these three diploid species is *L. puberula;* it has two subspecies and several varieties and forms. Subspecies *puberula* occupies a large area in the eastern United States; subsp. *pauciflora* seems to be of relatively recent origin and is found in a small area in western Louisiana and eastern Texas.

The other two diploid species, *L. siphilitica* and *L. cardinalis,* appear to me to be of more recent origin than the three diploids above, although they must have been evolved for a long time. *Lobelia siphilitica* var. *siphilitica* is closely related to *L. puberula* var. *puberula* f. *simulans. Lobelia siphilitica* var. *ludoviciana* was derived from var. *siphilitica* in the western part of the geographical range.

Although strong morphological characteristics distinguish *L. cardinalis* from *L. siphilitica,* cytogenetic evidence certainly suggests that these two species are related. It seems logical to me to consider that *L. cardinalis* was derived by some mutational process from a *siphilitica*-like ancestral species; the process involved changes in chromosome structure. The ancestral area of *L. cardinalis* appears to have been in the southeastern United States. Two subspecies were formed: subsp. *cardinalis* which spread north, south and west and to the Coastal Plain; and subsp. *graminea* which spread southwards along the Gulf of Mexico to Texas and Mexico and as far as Panama. The favorable climate and wide habitat range in the southern area, especially in Mexico, permitted the survival of many mutants in subsp. *graminea.* Some of these mutants have formed morphologically-distinct populations that have been recognized as varieties. McVaugh (1952) described the spread of *L. cardinalis* from south (Mexico and adjacent areas) to north as far as California. I consider that this is a secondary spread of *L. cardinalis* following its primary migration to Mexico from the southeastern United States by way of Texas. Dressler (1954) discussed the floristic relationships between Mexico and North America. He concluded that some temperate spermatophytes may have migrated to Mexico from eastern North America in the early Pleistocene. Martin and Harrell (1957) made some interesting observations on this problem.

McVaugh (1952) interpreted the evolution and relationships of *L. cardinalis* quite differently from the present author. McVaugh thought

that *L. rotundifolia* was the species most closely related to *L. cardinalis*, and that the center of origin of *L. cardinalis* was "from southern Mexico southward." The cytogenetic evidence now establishes the relationship of *L. cardinalis* and *L. siphilitica* and the latter species is obviously closely related to other blue-flowered species such as *L. puberula*. I consider that *L. cardinalis* was evolved in the southeastern United States.

The origins of two tetraploid species, *L. elongata* and *L. amoena*, remain to be discussed. *Lobelia elongata* is a tetraploid Coastal-Plain species. It appears to have originated by the crossing (accompanied by doubling of the chromosome number) of a diploid *puberula*-like ancestor and some other closely-related species, possibly an ancestral species that no longer survives. I would expect that this latter species had glabrous hypanthia, narrow calyx-lobes and glabrous stems.

The origin of *L. amoena* has been difficult to investigate. This tetraploid species also seems to me to have originated by hybridization accompanied by doubling of the chromosome number. On morphological grounds, there seems to be no doubt that one of the parents was similar to *L. puberula* var. *puberula* f. *simulans*. During 1957, I came to the conclusion that *L. amoena* had originated by hybridization of *L. puberula* var. *puberula* with one of the small-flowered species, perhaps not a species that can be recognized today but one of the species or ancestral species in the line between the ancestral stock of *L. flaccidifolia* and the ancestral stock of the small-flowered species including *L. nuttallii* to *L. gattingeri* (see fig. 1).

The present geographical range of *L. amoena* is well defined; the species occurs in the mountains and piedmont of western North and South Carolina, northern Georgia, and eastern Alabama. *Lobelia amoena* has several distinguishing morphological characteristics that should be explained by any hypothesis of its origin. The calyx-lobes are narrow and short (5–12 mm. long), the flowers are medium-sized, the anther-tubes are small (2.5–3.5 mm. long) and the filament-tubes are 5–7 mm long. The hypothesis that *L. amoena* has resulted from the hybridization of *L. puberula* var. *puberula* with a small-flowered species would explain these morphological characteristics.

I did not consider such an hypothesis very seriously until the fall of 1957 when I was able to grow some vigorous hybrids of *L. puberula* var. *puberula* × *L. appendiculata*. The $F_1$ hybrids were diploid and pollen-sterile and the hybrids were morphologically intermediate between the two parents. These hybrids, of course, were different from specimens of *L. amoena* since the hybrids have stronger *appendiculata* characteristics than are apparent in *L. amoena*. Thus *L. amoena* was not derived from this cross but the evidence suggests that *L. amoena* could have resulted from hybridization between *L. puberula* var. *puberula* and one of the small-flowered species or ancestral species.

SUMMARY

1. The author's conclusions on the relationships of twenty-one species of *Lobelia L.* section *Lobelia* are based on correlated data derived from taxonomic, ecological, cytological, and genetic studies.

2. There are fifteen diploid species, one species with both diploids and tetraploids, three tetraploid species, and two hexaploid species. The taxonomy of these species and their infra-specific taxa is discussed.

3. Three new combinations are proposed and some artificial interspecific hybrids are listed.

4. The phylogenetic relationships of the twenty-one species are discussed and a diagram illustrates the relationships.

5. There are four lines of speciation. In each of three lines, only a single diploid species has survived. The remaining eighteen species have evolved in one complex system of speciation in which there are three distinct subgroups: (i) seven small-flowered species; (ii) a subgroup of four narrow-leaved species; and (iii) seven medium- to large-flowered species.

6. *Lobelia cardinalis* is related to *L. siphilitica*.

BOTANY AND PLANT PATHOLOGY DIVISION, SCIENCE SERVICE,
CANADA DEPARTMENT OF AGRICULTURE,
OTTAWA, ONTARIO.

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# PLANT COMMUNITIES IN JACKSON COUNTY, ILLINOIS

ROBERT H. MOHLENBROCK

Jackson County lies in the southwestern section of Illinois. It is bounded on the west by the Mississippi River (fig. 1). Several rivers and large streams traverse the county, the most important being the Big Muddy River, Beaucoup Creek, and Kinkaid Creek. The Big Muddy cuts a deep trench in the Mississippi bluffs, running into the Mississippi River at the southwestern corner of the county. The area of Jackson County is approximately 603 square miles, making it the largest of Illinois' sixteen most southern counties. The highest point, between 840 and 860 feet above sea level, is located in T 10 S, R 2 W, Section 31. The lowest elevation, between 320 and 340 feet, occurs in T 11 S, R 4 W, Section 11, at the junction of the Big Muddy River and the Mississippi River.

Studies of the vegetation of Jackson County during the past few years have produced interesting data concerning the species which occur spontaneously. It has 1330 species recorded to date and ranks second in Illinois for the number of species of vascular plants reported for a county, being exceeded only by Cook County. It should be mentioned, however, that fully 300 of highly industrialized Cook County's some 1400 species have not been recorded during the past half century.

The large number of species for the county is due primarily to the wide variety of habitats found there. During the third advance (Illinoian) of Pleistocene glaciation into Illinois, a large portion of the county was covered with an ice sheet. Jackson is one of the few counties of Illinois which has both glaciated and unglaciated regions.

The Shawnee Hills cuts across the county. This range of bluffs, arising in the western section of the county and extending eastward, is composed primarily of sandstone. Distinct vegetation communities may be found on the very dry exposed blufftops and in the deep, dense, moist ravines. The southwestern corner of the county near the Mississippi River possesses massive limestone bluffs. Low swampy woods occur in both the western and northeastern sections of the county. Several artificial lakes (Lake Murphysboro, Campbell's Lake, etc.) provide stations for some unusual aquatics. Parts of the county formerly were covered by grasslands (Elk Prairie), but now the prairie vegetation is confined to remnants along railroads or atop the limestone bluffs. A large number of introduced species have been recorded from Jackson County. These have, for the most part, been found in the larger cities (Carbondale and Murphysboro) and along railroads and highways.

The great majority of native species is of southern or southeastern affinity (Jones & Fuller 1955, Mohlenbrock 1955).

The 1330 species thus far reported represent 53% of the nearly 2500

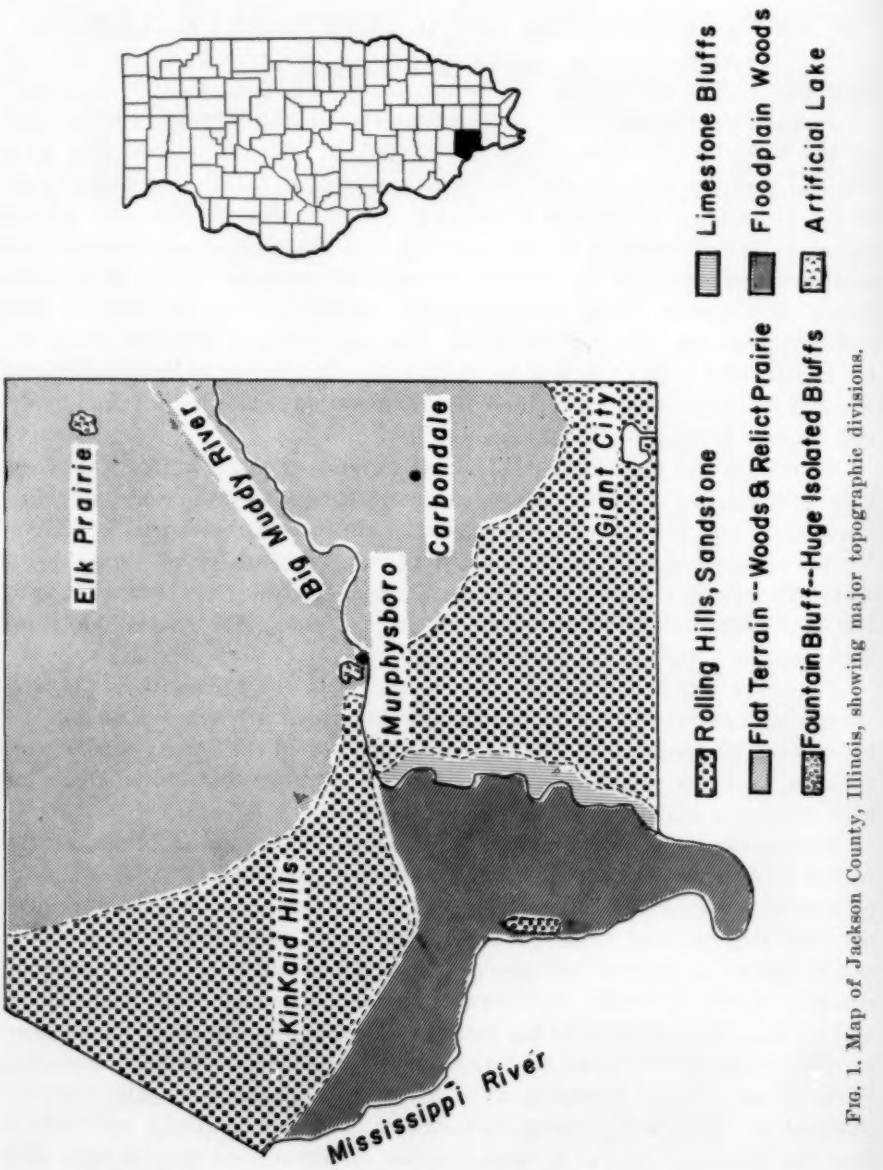


FIG. 1. Map of Jackson County, Illinois, showing major topographic divisions.

species known to occur in Illinois and 85% of those listed from the southern twelve counties. These species are distributed among 132 families.

The largest family is *Compositae* with 160 species. This is followed by *Gramineae* (grasses) with 147 species. Other large families are *Cyperaceae* (sedges) with 93 species, *Leguminosae* with 80, *Rosaceae* with 44, *Labiatae* (mints) with 43, *Scrophulariaceae* (figworts) and *Liliaceae* each with 35, and *Ranunculaceae* (buttercups) with 31 species. Forty-two species of ferns and fern-allies have been found in Jackson County.

Jackson County provides the only station in the southern eighteen counties for 111 species, the only station in the southern 55 counties for 67 species, and the only station in the southern 80 of Illinois' 102 counties for 38 species. Sixteen species are known in Illinois only from Jackson County. Three groups may be recognized: native species which include *Euphorbia vermiculata, Juncus diffusissimus, Prunus mexicana, Rubus alumnus, Synandra hispidula,* and *Gerardia fasciculata;* introduced species which include *Cyperus filicinus, Chenopodium polyspermum, Ranunculus parviflorus, Medicago arabica, Medicago orbiculata,* and *Physalis barbadensis;* and escapes from cultivation which include *Ruta graveolens, Cleome speciosissima, Spiraea prunifolia,* and *Myosotis sylvatica.*

In classifying the natural vegetation communities of Jackson County, a modification of a system first devised by Cowles (1901) is employed. The plants are divided into three series—river, swamp, and upland. Appended to this is a list of adventive species known from the county.

**The river series. A. The ravine.** As the ravine is formed by widening and deepening due to landslide action, lateral cutting, and side gullies, a considerable growth of vegetation develops. Ravine conditions are very favorable for plants. It is in these mesic woodland ravines that the most luxurious vegetation of southern Illinois is found. It is here that occur forests of beech, sugar maple, southern sugar maple, tulip tree, sourgum, species of hickory, and hackberry. Characteristic shrubs are the bladdernut (*Staphylea trifolia*) and spice-bush (*Lindera benzoin*) while some rare shrubs also occur. These are *Viburnum lentago* and *Rhus typhina,* two species known elsewhere in Illinois only from the northern counties. The herbaceous plants are for the most part vernal. Some of the more common are violets, Dutchman's breeches (*Dicentra cucullaria*), squirrel corn (*Dicentra canadensis*), trilliums (*Trillium flexipes, T. sessile,* and *T. recurvatum*), bloodroot (*Sanguinaria canadensis*), and harbinger-of-spring (*Erigenia bulbosa*). Rarer species such as blue-eyed Mary (*Collinsia verna*), *Viola cucullata, Valeriana pauciflora,* and various orchids (*Cypripedium parviflorum, Aplectrum hyemale, Corallorhiza wisteriana,* and *Orchis spectabilis*) occur in this habitat. A notable fall-flowering orchid, *Triphora trianthophora,* may be found in the mesic ravine at Little Grand Canyon. Many ferns also occur in the ravine woods.

These are the areas which have a rapid development into excellent forest lands because of the high collection and preservation of moisture due to intense shading.

Fig. 1. Map of Jackson County, Illinois, showing major topographic divisions.

Rocky ravines are common throughout Jackson County. Here precipitous slopes and bluffs occur and lateral cutting is slower. Rocky gorges are occasionally formed and these harbor a large number of mosses and liverworts on their dripping vertical walls. While most of the species of the clay ravines also occur in the sandstone rocky ravines, many additional ones find their occurrence here. The more exciting ones are *Lycopodium lucidulum* var. *occidentale*, *Asplenium trichomanes*, *Mitella diphylla*, *Saxifraga forbesii*, *Carex careyana*, *Allium tricoccum*, species of *Erythronium*, *Goodyera pubescens*, *Aralia racemosa*, *Dodecatheon frenchii*, *Synandra hispidula*, and *Mitchella repens*. The rocky ravines possess a greater number of rare southern Illinois species than any other physiographic area.

CHARACTERISTIC PLANTS OF THE MESIC RAVINES

*Acer barbatum*
*Acer saccharum*
*Adiantum pedatum*
*Aesculus discolor*
*Allium tricoccum*
*Aplectrum hyemale*
*Aralia racemosa*
*Arisaema triphyllum*
*Aristolochia serpentaria* (also on the rock hill slopes of the upland series)
*Asclepias exaltata*
*Asplenium trichomanes* (usually on the rock walls)
*Athyrium pycnocarpon*
*Athyrium thelypteroides*
*Campanula americana*
*Campanula rotundifolia* (usually on the rock walls)
*Camptosorus rhizophyllus*
*Carex careyana*
*Carex sparganioides*
*Celtis occidentalis*
*Collinsia verna*
*Cypripedium parviflorum*
*Delphinium tricorne*
*Diarrhena americana*
*Dodecatheon frenchii*
*Dryopteris hexagonoptera*
*Epifagus virginiana*
*Erigenia bulbosa*
*Erythronium albidum*
*Erythronium americanum*
*Euonymus obovatus*
*Fagus grandifolia*
*Goodyera pubescens*
*Hepatica acutiloba*
*Heuchera parviflora* var. *rugelii* (usually on the rock walls)
*Hypericum denticulatum*
*Isopyrum biternatum*
*Leersia virginica*
*Lindera benzoin*
*Liriodendron tulipifera*
*Magnolia acuminata*
*Mitella diphylla* (usually on the rock walls)
*Mitchella repens*
*Monotropa uniflora*
*Obolaria virginica*
*Onoclea sensibilis*
*Ophioglossum vulgatum*
*Orchis spectabilis*
*Panax quinquefolius*
*Phacelia purshii*
*Poa alsodes*
*Poa sylvestris*
*Rhus typhina*
*Saxifraga forbesii*
*Scutellaria nervosa*
*Solidago latifolia*
*Spigelia marilandica*
*Staphylea trifolia*
*Stylophorum diphyllum*
*Synandra hispidula*
*Trillium flexipes*
*Trillium recurvatum*
*Trillium sessile*
*Triphora trianthophora*
*Uvularia grandiflora*
*Uvularia sessilifolia*
*Valeriana pauciflora*
*Viburnum lentago*
*Viola cucullata*
*Woodsia obtusa*

B. **The river bluff.** Due to the deepening and widening of valleys, there is an increase in exposure to wind, sunlight, and changes of temperature and a decrease in the moisture content of the slopes. Mesophytic species are gradually replaced by more xerophytic ones. Many of the river bluffs in

Jackson County are limestone, although there is no paucity of sandstone.

Most of the limestone river bluffs occur along the Mississippi. Several species are confined in Jackson County to these bluffs—some found in small crevices, others on the talus so characteristic of limestone areas.

Numerous calcicolous ferns occur, the most characteristic being walking-fern (*Camptosorus rhizophyllus*), black spleenwort (*Asplenium resiliens*), tiny lip-fern (*Cheilanthes feei*), purple cliffbrake (*Pellaea atropurpurea*), and bulblet bladder-fern (*Cystopteris bulbifera*).

A few woody species are able to send their roots into the cracks and crevices of the bluff. These plants, because of the extreme environmental conditions to which they are subjected, are usually gnarled and stunted. Included in this group are buckthorn (*Rhamnus caroliniana*, dwarf hackberry (*Celtis pumila*), red cedar (*Juniperus virginiana*), and blue ash (*Fraxinus quadrangulata*). Several vines are found clinging tenaciously to the exposed faces of many of the limestone river bluffs. To mention a few, there are Virginia creeper (*Parthenocissus quinquefolius*), bur cucumber (*Sicyos angulatus*), snailseed (*Cocculus carolinus*), and two rare species, Dutchman's pipe-vine (*Aristolochia tomentosa*) and *Calycocarpum lyonii*.

Only a relatively few herbaceous species occur under such rigorous conditions. The most common ones of the bluffs are cleft phlox (*Phlox bifida*) and *Allium stellatum*, while plants associated with the talus include species of *Polymnia*.

Often mesophytic vegetation comes in at the foot of the bluffs and spreads out into the river valley.

CHARACTERISTIC PLANTS OF THE LIMESTONE RIVER BLUFFS

*Allium stellatum*
*Amorpha fruticosa*
*Ampelopsis arborea*
*Arabis pycnocarpa*
*Aristolochia tomentosa*
*Asplenium resiliens*
*Calycocarpum lyonii*
*Celtis pumila*
*Cheilanthes feei*
*Cocculus carolinus*
*Fraxinus quadrangulata*
*Juncus secundus*
*Juniperus virginiana*
*Onosmodium hispidissimum*
*Pellaea atropurpurea*
*Phlox bifida*
*Polymnia canadensis*
*Polymnia uvedalia*
*Prunus mexicana*
*Rhamnus caroliniana*
*Sicyos angulatus*
*Solidago radula*
*Sporobolus cryptandrus*
*Urtica chamaedryoides*

On loess hilltops above some of the limestone river bluffs are isolated small prairies. These relict areas are minute replicas of prairies to the West. Their origin and ecology have been thoroughly treated by Evers (1955) and will not be dwelled upon here. A list of species which are characteristic of the Jackson County hill prairies follows.

*Acerates viridiflora*
*Andropogon gerardii*
*Andropogon scoparius*
*Bouteloua curtipendula*
*Houstonia nigricans*
*Isanthus brachiatus*
*Koeleria cristata*
*Kuhnia eupatorioides*
*Liatris cylindracea*
*Petalostemum candidum*
*Petalostemum purpureum*
*Ratibida pinnata*
*Ruellia humilis*
*Silphium integrifolium*
*Solidago rigida*
*Sorghastrum nutans*

C. **The flood plain.** As ravines deepen and widen and approach the underground water level, the water remains for a longer time after each rainfall. As this occurs, certain hydrophytic species come into the area. Such a situation is developing in the Lake Murphysboro area, although here the ravines are apparently old enough so that embryonic streams are beginning to be formed. Here may be found the swamp buttercup (*Ranunculus septentrionalis*), *Plantago cordata,* species of *Polygonum* and *Carex,* numerous grasses, and others.

Where currents are rapid, little vegetation is able to anchor itself so that the flora associated with a fast flowing stream usually is sparse, save for some of the lower plants such as algae and mosses. As the energy from the stream is checked, the conditions for plant life become more favorable. Typical species to be found on gravelbeds and sandy shores of southern Illinois streams are *Commelina virginica, Lindernia dubia, Linum striatum, Hypericum mutilum, Lobelia cardinalis* and *L. siphilitica,* and a few grasses and sedges. Occasional shrubs such as *Salix sericea* and *Alnus serrulata* find the banks of streams ideal habitats.

Along the Mississippi River which, because of its enormous size, has somewhat different vegetation along it than does the Big Muddy, depositions of sand and silt have caused numerous sand bars to be formed. The vegetation of a newly formed sand-bar usually contains weedy species (*Ambrosia trifida, A. elatior,* and *Xanthium chinense*), along with *Juncus bufonius, J. tenuis, Eleocharis acicularis,* and other small sedges and rushes. Soon black willow and sand-bar willow (*Salix nigra* and *S. interior,* respectively) and cottonwood (*Populus deltoides*) appear on the bars. Whether the willows or the cottonwood appear first depends on which propagule is ready for ecesis at the time of emergence of the bar. Herbaceous species become established near the water and these may be found on nearly every sand bar of Jackson County. These include *Eragrostis hypnoides, Leptochloa, filiformis, Hemicarpha micrantha, Rumex fueginus, Potentilla paradoxa,* and species of *Bidens.* Away from the sand-bar are developing stands of river trees: river birch (*Betula nigra*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), and box elder (*Acer negundo*).

As the flood plain becomes older and aeration is improved, the development of a mesophytic forest proceeds. Willows and cottonwoods recede in favor of the more mesophytic forest trees such as basswood (*Tilia americana*), white ash (*Fraxinus americana*), black walnut (*Juglans nigra*), butternut (*Juglans cinerea*), and American elm (*Ulmus americana*). Grape

CHARACTERISTIC PLANTS OF STREAMS AND RIVERS

*Acer negundo*
*Acer saccharinum*
*Alnus serrulata*
*Arundinaria gigantea*
*Astragalus canadensis*
*Betula nigra*
*Bidens cernua*
*Bidens comosa*
*Bidens connata*
*Carex torta*
*Carex vulpinoidea*
*Cinna arundinacea*
*Commelina virginica*
*Cornus stolonifera*
*Cycloloma atriplicifolium*
*Cyperus pseudovegetus*
*Dianthera americana*
*Eragrostis hypnoides*
*Forestiera acuminata*
*Glyceria striata*
*Hemicarpha micrantha*
*Hypericum mutilum*
*Kyllinga pumila*
*Leptochloa filiformis*
*Linum striatum*
*Lobelia cardinalis*
*Lobelia siphilitica*
*Plantago cordata*
*Populus deltoides*
*Potentilla paradoxa*
*Rhexia virginica*
*Rumex fueginus*
*Salix interior*
*Salix nigra*
*Salix sericea*
*Scutellaria lateriflora*

vines (*Vitis* sp.) become abundant. The herbaceous layer in these river woods is exceedingly opulent although the floristic composition differs but little from that of the mesophytic ravine forests. One difference which is observed, however, is the presence in the river woods of more shrubs, a character which links the area to the forest swamps to be discussed later.

**The pond-swamp series.** Only rare and scattered natural sink-hole ponds occur in Jackson County although a larger number may be found in calcareous regions in Hardin County between Cave-in-Rock and Elizabethtown. In comparison to the fascinating coastal plain flora which occurs in some of the "sinks" in southern Missouri, the natural ponds in Jackson County provide the habitat for only one species not known elsewhere in southern Illinois. This is *Carex brachyglossa*.

However, the species which occur around ponds and the numerous artificial lakes are characteristic and should be discussed. The more quiet and stagnant bodies of water contain rare aquatic species of southern Illinois. For example, the relatively old Campbell's Lake near Elkville is rich in unusual species—*Azolla mexicana, Potamogeton pulcher, Wolffia columbiana, Wolffia punctata,* and *Nuphar advena*. Marginal and emergent vegetation includes cattail, water primrose (*Jussiaea diffusa*) and lizard's tail (*Saururus cernuus*).

CHARACTERISTIC PLANTS OF LAKES AND PONDS

*Azolla mexicana*
*Bacopa rotundifolia*
*Dianthera americana*
*Echinodorus rostratus*
*Eleocharis acicularis*
*Hottonia inflata*
*Lemna minor*
*Lemna valdiviana*
*Lophotocarpus calycinus*
*Myriophyllum heterophyllum*
*Myriophyllum verticillatum*
*Naias flexilis*
*Nelumbo lutea*
*Nuphar advena*
*Paspalum fluitans*
*Potamogeton americanus*
*Potamogeton diversifolius*
*Potamogeton friesii*
*Potamogeton pectinatus*
*Potamogeton pulcher*
*Proserpinaca palustris*
*Sagittaria brevirostra*
*Spirodela polyrhiza*
*Utricularia gibba*
*Wolffia columbiana*
*Wolffia punctata*

Through deposition and cycles of dryer climate, ponds and lakes may become more shallow and, should they be allowed to "dry-up," a new vegetation community develops. Should drainage be poor, or should springs occur, marshes appear. While southern Illinois is not a paludal region, one tiny "marsh" occurs just north of Murphysboro and provides a habitat for several unusual species in the Jackson County flora. The area is very spongy underfoot for most of the year.

CHARACTERISTIC PLANTS OF THE MARSH

*Carex comosa*
*Carex crinita*
*Carex lanuginosa*
*Carex tribuloides*
*Chelone glabra*
*Dryopteris thelypteris*
*Eupatorium perfoliatum*
*Iris virginica* var. *shrevei*
*Polygonum sagittatum*
*Ranunculus pusillus*
*Ranunculus sceleratus*
*Rosa palustris*
*Sagittaria latifolia*
*Scirpus cyperinus*
*Solidago patula*
*Typha latifolia*
*Viburnum recognitum*

Swampy forests occur in the southwestern and northeastern sections of the county. The area is extensive lowland in which occasional depressions containing standing water are present. The species growing in this habitat for the most part show an affinity to the southeastern flora. The dominant trees are pin oak (*Quercus palustris*), bur oak (*Q. macrocarpa*), and king-nut hickory (*Carya laciniosa*). In the wetter areas are found Drummond's red maple (*Acer drummondii*) and swamp cottonwood (*Populus heterophylla*). A shrub layer is very conspicuous in the swamp forests. Swamp holly (*Ilex decidua*), hawthorn (*Crataegus viridis*), and swamp dogwood (*Cornus foemina*) usually are common. A large number of grasses and sedges occur along with a few late summer perennials.

CHARACTERISTIC PLANTS OF THE SWAMPY FORESTS

*Acer drummondii*
*Carex caroliniana*
*Carex crus-corvi*
*Carex grayii*
*Carex lupuliformis*
*Carex lupulina*
*Carex muskingumensis*
*Carya illinoensis*
*Carya laciniosa*
*Cornus foemina*
*Diodia virginiana*
*Echinodorus cordifolius*
*Glyceria septentrionalis*
*Habenaria peramoena*
*Hydrolea affinis*
*Hymenocallis occidentalis*
*Leersia lenticularis*
*Leersia oryzoides*
*Oxypolis rigidior*
*Populus heterophylla*
*Polygonum opelousanum*
*Polygonum setaceum*
*Ptilimnium costatum*
*Quercus bicolor*
*Quercus lyrata*
*Quercus michauxii*
*Quercus palustris*
*Saururus cernuus*
*Sium suave*
*Taxodium distichum*

The amphibious flora of the roadside ditch is a most interesting one. Along Illinois Route 3 south of the Junction of Routes 3 and 144 are low ditches which are covered with water for a portion of each year. The vegetation is allied somewhat to that of the swampy forests. Among the species

of these ditches are *Isoetes melanopoda, Eleocharis smallii, Rhynchospora corniculata, Carex annectens, Ammannia coccinea, Callitriche heterophylla,* and *Phyllanthus caroliniensis.*

As some lakes become drained or begin to fill due to deposition, the margins begin to be encroached upon by sedges and rushes and eventually numerous grasses. Through this succession, prairies may develop. Although Jackson County is far to the south of the present prairie area of Illinois, some remnants, preserved along railways, may be found. The species which occur are equivalent to those found on the prairies to the West. One woody species (*Salix humilis*) and numerous more or less xerophytic herbs may be found. These include four species of *Silphium, Andropogon gerardii* and *A. scoparius, Sorghastrum nutans, Amorpha canescens, Baptisia leucantha, Coreopsis palmata, Liatris pycnostachya* and *L. squarrosa, Scutellaria leonardii, Ruellia humilis,* and many others.

**The upland series.** Besides the bluffs mentioned under the river series, there are hills which are not due primarily to erosive processes but to other causes. In our area, these are the rock hills. The most extensive of these is an east-west range of sandstone bluffs which extends across the entire state. It is known as the Shawneetown Ridge, or Ozark Hills. A portion of this ridge is located in Jackson County.

On the slopes of the south- and west-facing bluffs are oak-hickory woods characterized by a mostly homogeneous aggregation of vegetation dominated by white, black, and red oaks. The environmental conditions seem to be intermediate between the mesophytic ravine forests and the exposed rock hills. Few herbaceous species bloom in the spring, in contrast to the much larger number which flower during the summer and autumn.

CHARACTERISTIC PLANTS OF THE ROCK HILL SLOPES

*Asclepias variegata*
*Ascyrum multicaule*
*Asplenium platyneuron*
*Aster turbinellus*
*Brachyelytrum erectum*
*Bromus purgans*
*Carya glabra*
*Clitoria mariana*
*Cunila origanoides*
*Desmodium canescens*
*Desmodium laevigatum*
*Elephantopus carolinianus*
*Erianthus alopecuroides*
*Galium pilosum*
*Geum virginianum*
*Hexalectris spicata*
*Hieracium gronovii*
*Lespedeza hirta*
*Liatris scabra*
*Lobelia spicata*
*Panicum lindheimeri*
*Panicum linearifolium*
*Psoralea psoralioides*
*Quercus alba*
*Quercus rubra*
*Quercus velutina*
*Salvia lyrata*
*Solidago hispida*
*Spiranthes grayi*
*Swertia caroliniensis*
*Viola pedata*

The tops of these bluffs are mostly exposed sandstone and the vegetation that grows there is predominantly xerophytic. It is characterized by scrub oaks (*Quercus stellata* and *Q. marilandica*), red cedar (*Juniperus virginiana*), and winged elm (*Ulmus alata*). The shrubs are well represented by the sparkleberry (*Vaccinium arboreum*), highbush blueberry

(*Vaccinium vacillans*), and the fragrant sumac (*Rhus aromatica*). While only a few of the herbaceous species are vernal (*Hypoxis hirsuta, Nothoscordum bivalve*), a larger number flower during the summer when the temperature at rock surface occasionally reaches 115°. Those which belong to this summer aspect include *Oenothera linifolia, Opuntia humifusa, Tephrosia virginiana, Stylosanthes biflora, Linum medium,* and *Hypericum gentianoides.* A large number of grasses is characteristic of the area. The hairy lip-fern (*Cheilanthes lanosa*) is another common inhabitant.

CHARACTERISTIC PLANTS OF THE EXPOSED ROCK HILLS

*Agave virginica*
*Agrostis elliottiana*
*Aristida purpurascens*
*Asclepias verticillata*
*Aster anomalus*
*Bulbostylis capillaris*
*Carya texana*
*Cheilanthes lanosa*
*Crataegus engelmanii*
*Crotonopsis elliptica*
*Cyperus filiculmis* var. *macilentus*
*Danthonia spicata*
*Festuca octoflora*
*Hypericum drummondii*
*Hypericum gentianoides*
*Hypoxis hirsuta*
*Isanthus brachiatus*
*Juniperus virginiana*
*Krigia dandelion*
*Lechea minor*
*Linum medium*
*Nothoscordum bivalve*
*Oenothera linifolia*
*Opuntia humifusa*
*Plantago pusilla*
*Polygonum tenue*
*Quercus marilandica*
*Quercus stellata*
*Sedum pulchellum*
*Smilax bona-nox*
*Solidago buckleyi*
*Spiranthes gracilis*
*Stylosanthes biflora*
*Ulmus alata*
*Vaccinium arboreum*
*Vaccinium vacillans*

**Appended list of adventives of Jackson County.** Along highways and railroads are found a great number of species which are adventive in the area. While many of them are common "weeds," an occasional rarity does occur. Following is a list of some of the more unusual waifs so far collected in Jackson County.

*Aegilops cylindrica*
*Agropyron smithii*
*Anthemis nobilis*
*Bromus mollis*
*Celastrus orbiculatus*
*Chenopodium polyspermum*
*Chloris verticillata*
*Conringia orientalis*
*Cyperus schweinitzii*
*Datura innoxia*
*Daucus pusillus*
*Dyssodia papposa*
*Eriochloa contracta*
*Erucastrum gallicum*
*Holcus lanatus*
*Kickxia elatine*
*Lolium temulentum*
*Lythrum salicaria*
*Medicago arabica*
*Melissa officinalis*
*Mentha crispa*
*Ranunculus parviflorus*
*Ranunculus sardous*
*Rudbeckia amplexicaulis*
*Stellaria graminea*
*Tanacetum vulgare*
*Veronica persica*
*Veronica polita*

## SUMMARY

1. Jackson County lies in the southwestern section of Illinois. It covers an area of about 603 square miles. At present, 1330 species of vascular plants

are known from the county. This represents 53% of the species known from the state of Illinois.

2. In this study, the vegetation of the county is divided into several natural communities. Three series are recognized. The river series includes the floodplain, the river bluff, and ravine communities. The pond-swamp series is composed of lakes and ponds, the marsh, the swampy forest, and the prairie. In the upland series are the rock hill slopes and the exposed rock hill communities.

3. A list of adventive species in Jackson County is appended.

DEPARTMENT OF BOTANY, SOUTHERN ILLINOIS UNIVERSITY
CARBONDALE, ILLINOIS

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# A CHROMATOGRAPHIC STUDY OF THE FUNGUS EMERICELLOPSIS[1]

GRACE W. MAAG, L. W. DURRELL AND MERLE G. PAYNE[2]

A recent study of the fungus genus *Emericellopsis* has indicated that there are two distinguishable species, *E. mirabilis* (Malan) Stolk and *E. terricola*, Van Beyma (Durrell 1959). To further support this evidence a study was made of the free amino acids and amides in the five listed species of the genus and in the regional isolates and in 21 single spore variants from these forms.

Recently several workers have used chromatographic analysis for amino acids and sugars as a possible tool in distinguishing closely related forms of organisms.

Broyles (1952) found qualitative and quantitative differences in the amino acids and sugars present in the urediospores of certain races of cereal rust fungi. Crossan and Lynch (1958) found that qualitative differences existed among species and strains of several anthracnose fungi with respect to specific amino acids and sugars. Other workers have studied specific organisms from the standpoint of their nutritional requirements and their subsequent amino acid composition (DeVay 1954, DeVay and Stakman 1953, Hare 1953, Murray and Zscheile 1956, Pyle 1954).

Chromatography has been used as a taxonomic tool in other fields (Ball 1953, Buzzati-Traverso 1953, Buzzati-Traverso and Rechnitzer 1953, Hale 1956). Ginsburg, Lovett and Dunn (1956) using microbiological assay, were able to distinguish between 2 strains of a bacterium, one strain having a glutamic acid content much greater than that of the other. Micks (1956) found that three genera of mosquitoes could be distinguished readily by marked quantitative differences in their amino acid levels. Mattick, Berridge, Cheeseman and Mabbitt (1957) reported that intact bacterial cells, when washed and extracted with ten percent acetic acid, gave constant amino acid content. Every species gave a chromtographic pattern of spots and streaks different from that of every other species, but different strains within a species gave patterns with common properties. The examination of 73 strains of *Lactobacillus casei*—plantarum group has shown that chromatograms can be used to distinguish species in the group (Cheeseman, Berridge, Mattick, Bottazzi 1957). Also differences were found in various

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[2] Chemistry Section, Botany and Plant Pathology Section and Chemistry Section, Colorado Agricultural Experiment Station, Fort Collins, Colorado.

aged cultures but satisfactory consistency and differentiation of species were achieved by harvesting cells soon after the rate of increase of optical density in cultures begins to decline.

**Methods.** Five "species" or forms of *Emericellopsis* (*E. terricola,* Van Beyma; *E. terricola* var. *glabra,* Van Beyma; *E. mirabilis,* (Malan) Stolk; *E. minima,* Stolk; *E. humicola,* Cain; *E. salmosynnemata,* Grosklage and Swift; *E. terricola,* Colorado strain); and twenty-one variants from single spore isolations were grown in flasks containing 50 ml of standard Czapek Dox (Difco) solution. The nitrogen source in this medium was sodium nitrate and the carbon source, sucrose.

The flasks were held on a shake apparatus at room temperature until there was a heavy growth of mycelium (about 10 days). All cultures were examined for possible bacterial contamination before they were used in this study.

These samples of fungi grown in the liquid medium were centrifuged and the medium poured off. The fungi were washed three times with distilled water, centrifuging and pouring off the water each time. They were then placed on filter paper and sponged as dry as possible, before drying in a vacuum. A 15 mg sample of the finely ground material was placed in a centrifuge tube with 1 ml of ten percent isopropyl alcohol. This apparatus patterned after that of Takahashi (1951) consisted of a plastic rod cut and ground to fit a standard centrifuge tube. The plunger had spiral grooves on the surface to force the material to the bottom of the tube. It was turned by a motor at 3500 rpm for 10 minutes. After grinding, the sample was removed and stored over night in a stoppered glass vial. Within this time the free amino acids had dissolved in the ten percent isopropyl alcohol and the slurry had settled out.

The technique of paper partition chromatography used by Dent, Stepka and Steward (1947) was followed. For 1-dimensional chromatograms, 3 microliters of the supernatant liquid were placed on Whatman No. 1 filter paper (20 cm $\times$ 20 cm). The solvent used was 80 percent phenol (Merck-reagent grade). The chromatography was continued until the solvent nearly reached the top of the paper. Then the papers were removed and dried overnight at room temperature. The amino acid spots were revealed by dipping the dried sheets in 0.3% ninhydrin in 95 per cent alcohol. The amino acids in the spots of the 1-dimensional chromatograms were identified by running spots of the pure amino acids alongside those from the fungus extract and by separate two dimensional chromatograms (20 microliter spots) run in 80 percent phenol in one direction and lutidine saturated with water in the other direction. The amino acids of the 2-dimensional chromatograms were identified by their Rf values, their pattern on the chromatograms, and a spotting technique suggested by Dent, Stepka and Steward (1947).

The relative amounts of free amino acids in the samples were measured

by passing the dried ninhydrin stained 1-dimensional chromatograms through a Welch and Company densichron No. 2150, 18 hours or more after dipping in ninhydrin.[1] The densitometer readings were taken at 3 mm intervals, followed by plotting the optical density data on graph paper, measuring areas under curves with a planimeter, and expressing the various amino acid spots as percentages of the whole.

**Results and discussion.** The two-dimensional chromatograms of the fungus extracts revealed the presence of the following amino acids and amides: aspartic acid, glutamic acid, lysine, asparagine, serine, threonine, glutamine, tyrosine, gamma aminobutyric acid, valine, isoleucine and/or leucine, proline and an unknown spot. There was great variability in the quantitative amount of these amino acids even within a single species of *Emericellopsis*. No great difference was observed in the amount of gamma aminobutyric acid, valine and leucine and/or isoleucine but they showed a variable pattern between the species, within each species and in the various isolates that were included in the work. Aspartic acid and proline each occurred in small amounts and varied by appearing in some samples and being apparently absent in others. The outstanding observation was the high amount of lysine in *E. mirabilis* when compared with the other species.

The extent of variability within a species could be as great as that existing between species and would necessarily have to be determined. Therefore one-dimensional chromatograms were studied. These chromatograms showed four main amino acid spots. A variance analysis of these four main spots, expressed as percentages of the total, showed no significance except in spot 3, the one containing lysine. There was no significant difference in the total amino acids between species.

The relative amount of amino acids in spot 3, expressed as percentages of the total, is shown in Table 1. Table 2 gives the variance analysis of the spot containing lysine. This analysis shows there was significantly more lysine contained in the *E. mirabilis*, and its variants than in the other members of the genus and their variants.

Studies of 2-dimensional chromatograms of the strains within each "species" group indicated that the lysine spot accounted for the differences in spot 3 of the 1-dimensional chromatograms.

These data in Table 2 are in accordance with the recent work of Durrell (1959) in which he lists only two different species, *E. mirabilis* and *E. terricola*, in the genus Emericellopsis.

## SUMMARY

1. The following free amino acids and amides were found in the species and isolates of the fungus *Emericellopsis;* aspartic acid, glutamic acid,

[1] Chromatograms dyed with ninhydrin will hold their original densities for over one year at 0° F.

lysine, asparagine, serine, threonine, glutamine, tyrosine, gamma aminobutyric acid, valine, isoleucine and/or leucine, proline and an unknown spot.

TABLE 1. *Relative concentration of the amino acids in spot 3, 1-dimensional chromatograms. (lysine glutamine and serine) among the species and isolates of* Emericellopsis *expressed in percent of total.*

| *E. mirabilis* | *E. terricola* + *E. salmosynnemata* | *G. humicola* | *E. minima* |
|---|---|---|---|
| Percent of total | Percent of total | Percent of total | Percent of total |
| 0.43 | 0.16 | 0.31 | 0.34 |
| 0.49 | 0.19 | 0.33 | 0.35 |
| 0.54 | 0.19 | 0.33 | 0.35 |
| 0.62 | 0.20 | 0.35 | 0.37 |
| 1.00 | 0.20 | 0.39 | 0.42 |
| 1.10 | 0.21 | 0.42 | 0.46 |
| 1.65 | 0.21 | 0.45 | 0.50 |
| 1.95 | 0.22 | 0.49 | |
| 2.02 | 0.22 | 0.50 | |
| 2.23 | 0.22 | | |
| 2.46 | 0.22 | | |
| 2.65 | 0.22 | | |
| | 0.25 | | |
| | 0.25 | | |
| | 0.27 | | |
| | 0.27 | | |
| | 0.27 | | |
| | 0.28 | | |
| | 0.29 | | |
| | 0.32 | | |
| | 0.32 | | |
| | 0.35 | | |
| | 0.35 | | |
| | 0.36 | | |
| | 0.38 | | |
| | 0.41 | | |
| | 0.42 | | |
| | 0.43 | | |
| | 0.47 | | |
| | 0.50 | | |
| | 0.50 | | |
| | 0.52 | | |
| | 0.53 | | |
| | 0.54 | | |

TABLE 2. *Analysis of variance of the relative concentration of amino acids in spot 3, in 1-dimensional chromatograms.*

| Source | DF | Mean Squares |
|---|---|---|
| Treatment | 3 | 3.8310* |
| E. mirabilis vs. minima humicola and terricola | 1 | 11.4203** |
| among minima, humicola, and terricola | 2 | 0.0362 |
| Residual | 58 | 0.1378 |

* significant at the 5 percent level.
** significant at the 1 percent level.

2. There was considerable variability in the quantitative amount of these amino acids within and between species.

3. A variance analysis showed that there was significantly more lysine in the *E. mirabilis* species and its isolates than in the other members of the genus.

4. These data support the evidence for two species, i. e. *mirabilis* and *terricola* in the genus *Emericellopsis*.

DEPARTMENT OF CHEMISTRY, COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

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# STUDIES ON LICHEN GROWTH RATE AND SUCCESSION

MASON E. HALE, JR.

As part of a broad program of lichen studies, a number of permanent stations for recording lichen growth rate and succession have been set up in Aton Forest, a research area in northwest Connecticut. The lichen flora of this area (Hale 1950) and the first report on these studies (Hale 1954) have already been published. This second report summarizes the results accumulated during the first nine years.

**Rock stations.** In the first report, covering about three years, a number of tentative values for radial growth were listed. These were determined by superimposing plastic sheets on which outlines of the thalli had been traced and measuring the increase in radius at several points around the thalli. Actually so little growth had occurred that accurate measurements were not possible. The total growth for nine years, however, is so great that errors in the tracing operation are now minimized and more precise values can be presented. The average annual radial growth rates (calculated from a period of eight years and nine months) for six species are listed below.

| | |
|---|---|
| *Crocynia membranacea* | 0.55 mm. |
| *Diploschistes scruposus** | 0.44 mm. |
| *Lecidea coarctata** (with apothecia) | 1.4 mm. |
| *Parmelia isidiata* (mature thallus) | 1.6 mm. |
| *Parmelia isidiata* (juvenile thallus) | 0.8 mm. |
| *Rhizocarpon grande** | 0.33 mm. |
| *Rinodina oreina* | 0.57 mm. |

Values for species marked with asterisks were obtained by measuring the advance of the thalli into the drilled corner holes, 2 cm. in diameter, which mark the quadrats. The one measurement made in 1958, divided by eight years and nine months, gave the above annual rates. We must assume, probably correctly, that the lichens were present at the very edge of the drilled holes nine years ago, for otherwise the growth rates would be slightly greater than those calculated above.

The most precise measurements were made for *Parmelia isidiata* and *Rinodina oreina,* the dominant saxicolous species in the region. The positions and outlines of numerous thalli have been traced on the plastic sheets on three different occasions, 1949, 1952, and 1958. When the tracings are superimposed (fig. 1), the growth patterns become strikingly clear, and the annual rate of growth may be calculated from the known area of approximately orbicular thalli with the formula $A = \pi r^2$ so that the radius equals the square root of the known area in $cm^2$. divided by 3.14. For example the calculated radius of the thallus marked 1949 in figure 1 is 2.1 cm., that of

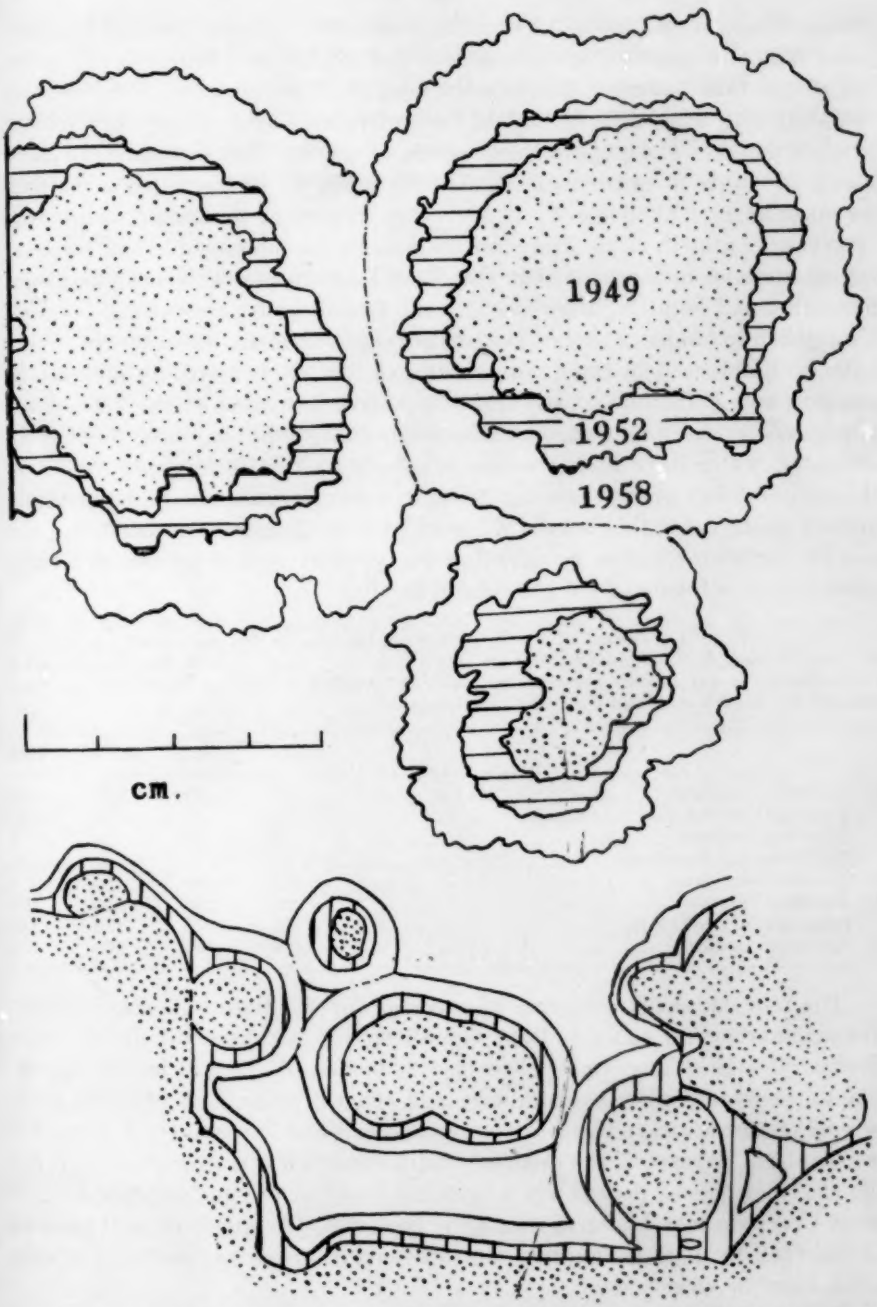


FIG. 1. Outlines of thalli of *Parmelia isidiata* (upper drawing) and *Rinodina orcina* (lower drawing) taken from superimposed plastic sheets. Stippling represents the original thalli, hatching the growth between 1949 and 1952, and the unmarked area the growth between 1952 and 1958.

the thallus marked 1958 is 3.5 cm. The remainder, 1.4 cm., divided by eight years and nine months, gives a growth rate of 1.6 mm. annually. It is believed that this technique provides the most accurate measure of the over-all radial growth without reference to the individual lobes, which vary widely in growth rate. Many published values of growth have apparently been based on single measurements of selected lobes. If we use such a method, we must be careful to specify if the values represent maximum, minimum, or averaged growth rates. The chief obstacle to the continued use of an area-radius method, however, is that the thalli tend to lose their orbicular configuration and identity, after meeting and fusing with neighboring colonies. Two juvenile thalli of *Parmelia isidiata* (2–4 mm. in diameter in 1949) have been observed in the quadrats. In the first three years no increase in size was noted. In the last six years they have increased at the rate of 0.8 mm. per year, only half the rate of mature thalli (that is, those 3–9 cm. in diameter, which have been growing regularly at 1.6–1.8 mm. per year). If this initially slow growth rate can be interpreted as evidence of a logarithmic growth pattern for this lichen, we would not be justified in estimating the age of a mature thallus by dividing the present radius by the presently observed growth rate of 1.6 mm. per year.

TABLE 1. *Coverage in cm.² of the dominant cryptogams in five rock quadrats (21 × 27 cm.) at Hickory Hill. In quadrat 1 there was a loss of 41 cm.² of* Parmelia isidiata *after 1955, leaving a net loss in coverage in 1958. In quadrat 3* Lecidea coarctata *has been overrun by dead leaves and* Crocynia membranacea.

| | 1949 | 1952 | 1955 | 1958 |
|---|---|---|---|---|
| 1. *Parmelia isidiata* | 242 | 367 | 388 | 385 |
| *Rinodina oreina* | 13 | 17 | 18 | 23 |
| 2. *Parmelia isidiata* | 38 | 39 | 28 | 4 |
| *Ptilidium pulcherrimum* | — | — | — | 170 |
| 3. *Lecidea coarctata* | 210 | 186 | 100 | 4 |
| 4. *Rinodina oreina* | 227 | 232 | 250 | 277 |
| *Lecanora* cf. *gibbosula* | 172 | 175 | 178 | 182 |
| 5. *Parmelia isidiata* | 124 | 191 | 260 | 305 |

The four consecutive records of coverage for the more important species are summarized in table 1. Data for all species are kept on file at Aton Forest. As was evident in the first report, profound changes in the vegetation on rocks take place continuously and often rapidly. Loss of thalli from several quadrats has reduced total coverage and also exposed fresh areas for colonization. Several of the quadrats deliberately chosen nine years ago for the study of foliose lichens are now being overrun by the undifferentiated crust *Crocynia membranacea* and by bryophytes. The quadrats will have to be observed for perhaps another ten to twenty years before patterns of succession can be clearly seen.

**Soil stations.** The soil lichens transplanted to Aton Forest have fared very poorly. All transplants of arctic species from Baffin Island have appar-

ently disappeared. At Hickory Hill, only two of nine plots still have any trace of the original lichens, one with *Cetraria islandica* and the other with *Cladonia uncialis*. The following species had disappeared by 1955, five to six years after transplantation: *Cladonia alpestris, C. decorticata, C. mateocyatha, C. turgida, Baeomyces roseus,* and *Peltigera canina*. These species have been replaced by dense *Polytrichum* mats.

SUMMARY

1. The results of studies on the growth rates of six lichens are summarized for a period of about nine years.

2. The foliose species *Parmelia isidiata* has grown regularly at the rate of 1.6 mm. per year in radius.

3. Crustose species increased in radius from .33 to 1.4 mm. per year.

4. Records of coverage in the rock quadrats and a summary of the soil stations are also presented.

SMITHSONIAN INSTITUTION
WASHINGTON 25, D. C.

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# BINOMIAL COMBINATIONS RELATED TO POLYPORUS ACANTHOIDES FR.[1]

OSWALDO FIDALGO[2]

The name *Boletus acanthoides* first appeared in mycological literature when used by Bulliard (1790, t. 486) for his illustration of a polypore with a zonate pileus and minute regular pores. Although it cannot be ascertained from his illustration, Bulliard's name indicates that his fungus may have lacerate dissepiments. Fries (1821, p. 356) subsequently placed Bulliard's species in synonymy with *Polyporus giganteus* Pers. ex Fr., and in the same publication (p. 351) he validated as *P. rufescens* Pers. ex Fr., Persoon's *Sistotrema rufescens* described in the Synopsis (1801, p. 550) and illustrated in Icones Pictae (1803, t. 6). Persoon's illustration of this species depicts a fungus that is similar to *B. acanthoides* Bull. in general aspect, but appears to be nearly azonate and with daedaloid or irpicoid pores.

Fries later (1838, p. 448) seemed to change his concept of these species, as he described *Polyporus acanthoides* Fr., and referred to it not only Bulliard's illustration of *Boletus acanthoides* but also Persoon's illustration of *Sistotrema rufescens*. Fries (1838) retained *Polyporus rufescens* as a separate species, but based this distinct concept on a subspecific division of Persoon's *S. rufescens* (1825, **2**: 206). In his Hymenomycetes Europaei, Fries (1874, p. 540) retained the same concept of *P. acanthoides* that he had presented in the Epicrisis and included *P. acanthoides* of Kickx (1862, **2**: 227), of Quélet (1872, p. 274), *B. acanthoides* Bull. (1789, t. 486), *S. rufescens* Pers. (1803, t. 6) and probably *Hydnum crispum* Inzenga (1869, t. 6, f. 1) as representing his interpretation of this species.

It was Quélet (1888) who apparently first reestablished the distinction between *Boletus acanthoides* of Bulliard and *Polyporus acanthoides* of Fries as presented in the Epicrisis and Hymenomycetes Europaei. Quélet (pp. 406–407) discussed *B. acanthoides* as *Caloporus acanthoides*, cited Bulliard's table 486, and included *Boletus giganteus* Pers. (1801, p. 521) as a synonym. He also suggested (pp. 407–408) that *P. acanthoides* of Fries in the Hymenomycetes Europaei (p. 540) may be synonymous with *Cerioporus montanus* Quél.

[1] A study made with the aid of a grant from the National Council of Research of Brazil in the National Fungus Collections, Plant Industry Station, Beltsville, Maryland, U. S. A.

[2] "Naturalista" of the "Jardin Botanico do Rio de Janeiro" and "Instrutor" of the "Faculdade Nacional de Filosofia da Universidade do Brasil", Rio de Janeiro, Distrito Federal, Brasil.

Patouillard (1897, p. 47), Lloyd (1910, p. 38) Killermann (1922, pp. 67–68), Bourdot and Galzin (1928, p. 523), Bresadola (1931, tab. 972) and Bondarzew (1953, p. 605) accepted the view that *B. acanthoides* Bull. is synonymous with *Polyporus giganteus* Pers. ex Fr.

FIG. 1. *Boletus acanthoides* Bull. in Bulliard, P. 1790. Histoire des champignons de la France. Paris. Atlas 3: 486. It was indicated by Fidalgo (1958) as type of *Polyporus acanthoides* Bull. ex Quél. (non *P. acanthoides* Fr).

According to Lloyd (1910, p. 38), "*Polyporus acanthoides* is based on an old figure of Bulliard (t. 486) which appears to be a very poorly colored picture of *Polyporus giganteus*, and was used as a juggle for *giganteus* in

FIG. 2. *Sistotrema rufescens* in Pers., C. H. 1803. Icones pictae specierum rariorum fungorum. 1: pl. VI. Fries used this picture to illustrate the *Polyporus acanthoides* Fr. It was indicated by Fidalgo (1958) as type of this species.

Quélet's later works. The picture is so poor that Fries mistook it, and *Polyporus acanthoides* in the sense of Fries is *Polyporus rufescens* (or *biennis*, if you wish). This is proven from a specimen labeled *Hydnum*

*crispum* by Inzenga and cited by Fries, and still preserved in his herbarium." Bresadola (1931, t. 957) agreed that *H. crispum* Inzenga is "forma

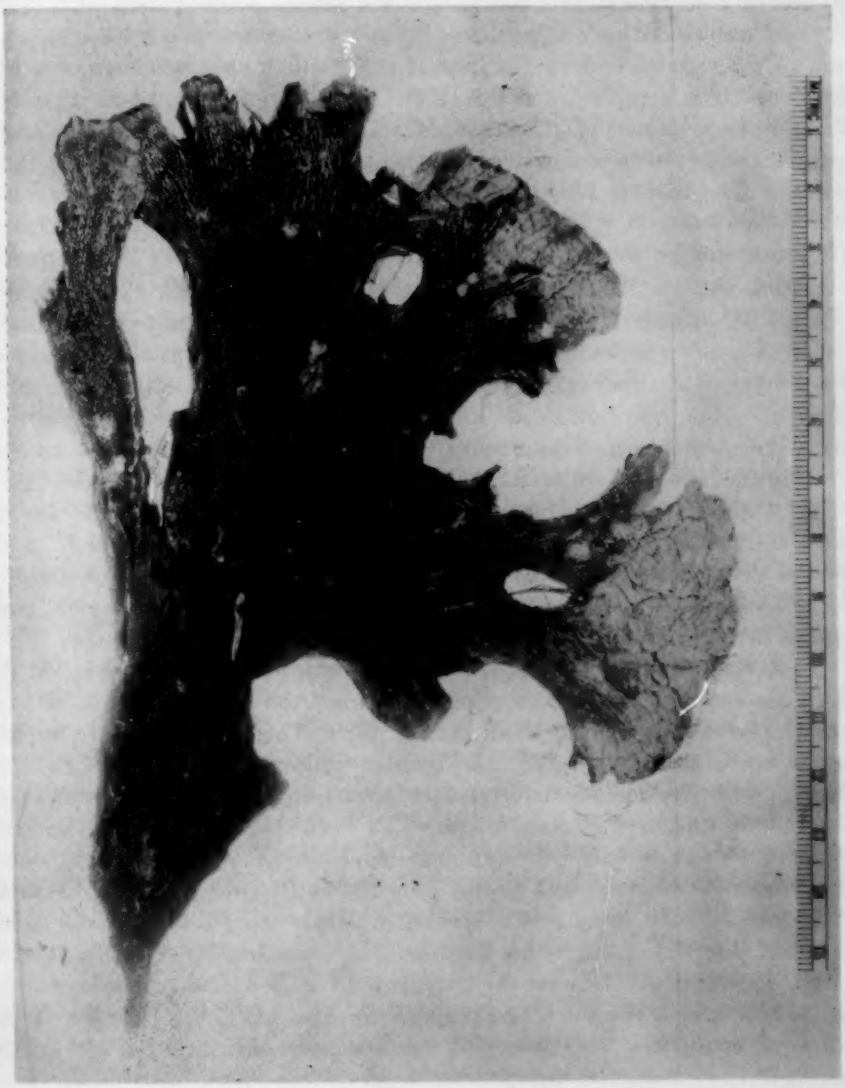

FIG. 3. *Polyporus acanthoides* Fr.-*Heteroporus biennis* (Bull. ex Fr.) Lazaro. Specimen determined as *Hydnum crispum* Auct. non Schaeff. ex Fr.: Inzenga, see Fung. Sic. 52, t. 6, f. 1. 1869. Only specimen named by Fries as *P. acanthoides* Fr. (non *P. acanthoides* Rostk. nec *P. acanthoides* Bull. ex Quél. Loc. Sicilia. It is deposited in the Mus. Botan. Upsaliense.

exsiccata *rufescens*," and a specimen in the BPI, collected by Killerman, has been determined by Bresadola as *Polyporus acanthoides* (Bull.) Fr.

with *P. rufescens* (Pers.) Fr., *P. biennis* Bull. var. and *H. crispum* Inzenga noted as being synonyms.

Another complicating element was introduced when Velenovsky (1922, p. 662) published under the name *Polyporus acanthoides* Bull. a description of a specimen collected in Sumave. Although this specimen was misdetermined, it was accepted by Pilát (1936, pp. 50–51) as representing Fries' interpretation of *P. acanthoides* as presented in the Epicrisis, and was the basis for the new combination *Grifola acanthoides* (Fr.) Pilát. Later, Pilát (1937, p. 146) cited this fungus as *P. acanthoides* Velenov. and placed the name in synonymy with *Phaeolus croceus* (Pers. ex Fr.) Pat. The fungus of Velenovsky should, instead, have been cited as *P. acanthoides* auct. non Fr. nec Bull.: Velenov., České Houby 662. 1922. *G. acanthoides* (Fr.) Pilát, which is based on Velenovsky's specimen, is to be regarded either as a new species, having the Velenovsky specimen as the type, or as a synonym of *Polyporus croceus* Pers. ex Fr. It is not related to *P. acanthoides* Fr. since, according to Pilát's description and statement, Velenovsky's specimen has no relationship with *Polyporus biennis* (Bull. ex Fr.) Fr. Figures 10–15 of Pilát (1936) were reproduced by Bondarzew (1953, p. 611), and the spores drawn as no. 2 of Bondarzew's figure 168 are the same as Pilát's figure 11. This figure in Pilát's work represents *G. acanthoides*. The reproduction of the figure in Bondarzew's work is labelled *Polypilus acanthoides*, this combination being based on Velenovsky's specimen as interpreted by Pilát.

It is clear that *Polyporus acanthoides* as interpreted by Fries in the Epicrisis and Hymenomycetes Europaei is not the same species as *Boletus acanthoides* illustrated by Bulliard in 1789. Therefore, Bulliard's plate cannot serve as the type for this Friesian concept. Without this element, Persoon's illustration of *Sistotrema rufescens* appears to be the best available representation of *P. acanthoides* of Fries (1838 and 1874). In the Fries herbarium there is only one specimen named by Fries as *P. acanthoides*. This specimen was sent to Fries by Inzenga as *Hydnum crispum*. At first, Fries considered it to be a new species, which he named *Sistotrema flabellare*, but later he changed his opinion and wrote on the label: "Corr.—*Polyp. acanthoides.*" During the present study this specimen was examined and found to be a specimen of *Polyporus biennis* (Bull. ex Fr.) Fr. in the rufescent condition. The spores of the specimen measure $4–5 \times 3–4\mu$, the basidia $18–25 \times 5–7\mu$ and the cystidia $30–40 \times 6–8\mu$. Therefore, this specimen and Persoon's plate of *S. rufescens* represent the same species.

## SUMMARY

1. *Polyporus acanthoides* Fr. (1838 and 1874), is distinct from *Boletus acanthoides* Bull. and from *Polyporus montanus* (Quél.) R. Ferry, but is synonymous with *P. biennis* (Bull. ex Fr.) Fr. Persoon's figure (1803, t. 6)

of *Sistotrema rufescens* which is cited by Fries and which is synonymous with *P. biennis* is therefore selected as the lectotype of *P. acanthoides* Fr.

2. *Polyporus acanthoides* Rostk. (1848, III (4), 27–28 heft, p. 37, tab. 19 (1–2).) later homonym of *Polyporus acanthoides* Fr. is considered a synonym of *Polyporus giganteus* Pers ex Fr.

3. *Boletus acanthoides* Bull. (1790, t. 486) was placed in synonymy with *Polyporus giganteus* Pers. ex Fr. by Fries (1821) but was not validated by him at this time nor later (1838) when *Polyporus acanthoides* Fr. was described and also not by Quélet (1872 and 1886) who during this time followed entirely Fries (1838 and 1874). Therefore, *B. acanthoides* Bull. appears validated by Quélet only in 1888 as *Caloporus acanthoides* (Bull.) ex Quél. The combination *Cladomeris acanthoides* (Fr.) Quél. (1886, p. 168) should be considered in synonymy with *P. acanthoides* Fr. and misapplied by Bigeard and Guillemin (1909, p. 410) as synonym of *Cerioporus montanus* Quél. However, in the same work (p. 409) the combination *Cladomeris acanthoides* (Bull. ex Quél.) Bigeard & Guill. is also found in synonymy with *Polyporus giganteus* Pers. ex Fr.

4. *Polyporus acanthoides* in Velenovsky's sense is a misdetermination of *P. acanthoides* Fr. but referred to Bulliard. In reality it is neither *Boletus acanthoides* Bull. nor *P. acanthoides* Fr. On this misdetermined specimen are based the combinations *Grifola acanthoides* (Fr.) Pilát and *Polypilus acanthoides* (Fr.) Bond. According to the art. 55 of the Code, these combinations, even applied erroneously, must figure under the synonymy of *Polyporus acanthoides* Fr. If Velenovsky's specimen is really *Polyporus croceus* Pers. ex Fr., as suggested by Pilát (1937, p. 146), the combinations *Grifola acanthoides* and *Polypilus acanthoides* can be indicated also after the synonymy of *Polyporus croceus* Pers. ex Fr. followed by the words auct. non Fr., according to the recommendation 50F of the Code, but if it is recognized as a new species, it must receive a new name.

5. *Polyporus acanthoides* Britz., as referred by many authors, does not exist since it was never described. Figures 90 and 93 of Britzelmayr (1890 and 1894) named as *P. acanthoides* are referred to Bulliard. Both are very poor pictures but, in general, the authors agree that they may represent *Polyporus confluens* Alb. & Schw. ex Fr. If so, after the synonymy of *P. confluens* Alb. & Schw. ex Fr., Britzelmayr's misinterpretation can be indicated, according to the code as *Polyporus acanthoides* auct. non Bull. ex Quél.: Britzelmayr, M. Hymenomyceten aus Sudbayern X, Bericht des naturwissenschaftlichen vereins fur Schwaben und Neuberg, **31**: 217. 1894. The pictures were published before in the part VI (1890) but then no author was mentioned after the specific name.

FACULDADE NACIONAL DE FILOSOFIA DA UNIVERSIDADE DO BRASIL
AV. PRESIDENTE ANTÔNIO CARLOS—40, 70. ANDAR
RIO DE JANEIRO—DISTRITO FEDERAL—BRASIL

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FIG. 1—**Bulliard**'s pl. 486 of *Boletus acanthoides* **Bull.**

FIG. 2—**Persoon**'s pl. 6 of *Sistotrema rufescens* **Pers.**

FIG. 3—Specimen determined as *Hydnum crispum* **auct. non Schaeff. ex Fr.: Inzenga,** Fung, Sic. 52, t.6, f.1. 1869. Only specimen named by **Fries** as *P. acanthoides* **Fr.** (non *P. acanthoides* **Rostk.** nec *B. acanthoides* **Bull.**)

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# TORREYA

## A Color Variant of Habenaria Cristata

G. M. CARPENTER

During the second and third weeks of August, 1958 four orchids were discovered growing in Monmouth and Middlesex counties, New Jersey, which corresponded to the description given by Correll (1950, pp. 14–15 and 49–53) for *Habenaria cristata* (Michx.) R. Br., except in the criterion of perianth color. Descriptions given for this species of *Habenaria* indicated that the flowers were orange, while the ones under discussion were light cream colored and bordering on off white. A review of literature, e.g., Correll (1950), Fernald (1950), Niles (1904), Morris & Eames (1929), and Gleason (1952) yielded no variation similar to this and so a study was made to more clearly determine their nature.

Following is a description of the variants. Plants glabrous, leafy below, bracted above. Leaves two to three, acute to accuminate, sheathing the stem, mean length to width ratio 7.3:1 (8.7–14.7:1.4–1.9 cm.). Only those appendages sheathing the stem were here considered leaves, all others were bracts. Foliaceous bracts present, diminishing to floral bracts in the inflorescence. Floral bracts narrowly lanceolate-accuminate, equalling or shorter than pedicellate ovaries. Flowers light cream color with slender pedicellate ovaries. Petals, mean length to width ratio 1.7:1 (.25–.35:.15–.20 cm.), cuneate, toothed to minutely fringed at apex. Dorsal sepals, mean length to width ratio 1.2:1 (.30–.40:.25–.35 cm.), concave with obtuse apex. Lateral sepals, mean length to width ratio 1.2:1 (.30–.40:.25–.30 cm.), rounded at the apex. Lips ovate, copious ciliate fringed, with the segments often branched. Spurs long, slender, and about half the length of ovaries.

The two populations studied were a distance of 7.5 miles from each other. In one population the variants and *H. cristata* were present, while only one variant and no *H. cristata* was found in the other station. Eight flowers were removed from all plants. Three were preserved and the remainder dissected with the following observations recorded: (1) plant heights, ground to inflorescence apices; (2) raceme heights, lowest floral attachment to inflorescence apices; (3) Lip widths, widest point excluding fringe; (4) fringe lengths, longest and shortest and three intermediate, both sides, measured .76 mm. from apices; (5) fringe number in same distance; (6) greatest length and width of petals, dorsal and lateral sepals; (7) spur length; (8) greatest length and width basal leaf. The mean, standard deviation, and standard error are presented in Table 1. Since the measurement ranges for morphological characteristics as cited by Correll (1950) included the ranges given by various other authors they have been included for comparison in Table 1.

The variant was given a color designation by the author on the Nickerson Color Fan (American Horticultural Council, 1957) of "much nearer white than 2.5 y 9/9," while the flowers of *H. cristata* were given the value 5yR 7/11 (strong orange). Fernald (1950) listed the variation in flower color of *Habenaria cristata* as "yellow to orange," however the specimens found in New Jersey could, under no circumstances be termed yellow.

A herbarium specimen of *Habenaria cristata* with the following annotations was located: "Flora of New York, C. S. Bryan, Montauk Point, August 1948, in humus mixed with sand, corolla pale cream color," AMES. (See Lanjouw, 1954). Although no measurements were taken, and perianth color was impossible to determine from the specimen, it is highly probable that it was similar to the variants collected in New Jersey.

The statistics computed in Table 1 indicate that the cream colored variant was sufficiently close to *Habenaria cristata* to be considered within the variation of this species, and therefore its perianth color should be included in the total variation of *H. cristata* in the literature.

The population in which both colors of *Habenaria cristata* occurred was found near Farmingdale, Monmouth county, New Jersey. The plants were scattered along a roadside

Table 1. Measures of Aggregation and Dispersal in Populations of Habenaria Cristata*

| Characteristics | H. cristata—orange | | | H. cristata—cream | | | Correll Range for H. cristata† |
|---|---|---|---|---|---|---|---|
| | Mean | S. Dev. | S. Error | Mean | S. Dev. | S. Error | |
| Plant height | 19.79 | 3.50 | 2.02 | 26.00 | 5.54 | 2.77 | 18.0–90.0 |
| Raceme height | 2.41 | 0.64 | 0.37 | 4.14 | 1.27 | 0.63 | 2.0–15.0 |
| Lip width | 0.21 | 0.02 | 0.001 | 0.19 | 0.001 | 0.001 | —— |
| Fringe length | 4.50 | 2.18 | 0.17 | 4.14 | 1.83 | 0.18 | —— |
| Fringe number | 10.40 | 1.45 | 0.25 | 10.40 | 2.04 | 0.32 | —— |
| Dorsal sepal length | 0.36 | 0.04 | 0.01 | 0.36 | 0.12 | 0.03 | .3– .5 |
| Dorsal sepal width | 0.30 | 0.02 | 0.05 | 0.29 | 0.27 | 0.01 | .2– .3 |
| Petal length | 0.34 | 0.03 | 0.01 | 0.32 | 0.30 | 0.01 | .2– .4 |
| Petal width | 0.19 | 0.02 | 0.01 | 0.18 | 0.03 | 0.01 | .1– .2 |
| Lateral sepal length | 0.38 | 0.03 | 0.01 | 0.37 | 0.03 | 0.01 | .3– .4 |
| Lateral sepal width | 0.30 | 0.06 | 0.01 | 0.29 | 0.01 | 0.03 | .2– .3 |
| Spur length | 0.56 | 0.05 | 0.001 | 0.52 | 0.02 | 0.001 | .5– .1 |
| Leaf length | 8.23 | 0.57 | 0.32 | 10.92 | 1.78 | 0.89 | 7.0–21.0 |
| Leaf width | 1.35 | 0.12 | 0.07 | 1.54 | 0.25 | 0.12 | 1.0– 2.5 |

* Given in centimeters except for fringe length which is given in millimeters and fringe number where the actual number is indicated.
† Correll (1950) p. 67.

two miles east-south-east of Farmingdale. They were partially shaded and growing in damp sandy loam soil. The plants were associated with *Acer rubrum, Sassafras albidum, Pinus rigida, Quercus alba, Vaccinium vacillans, Itea virginica,* and small plants and seedlings of *Ilex glabra.*

The Middlesex county population, where only one of these cream colored variants was found was in a depressed swampy area beneath high tension wires 1.1 miles south of Cottrell Corners, and 1.5 miles east-south-east of Browntown. The *Habenaria* was growing partly shaded in association with *Acer rubrum, Nyssa sylvatica, Pinus rigida, Vaccinium atrococcum, Magnolia virginiana, Pteridium aquilinum, Andropogon virginicus* var. *abbreviatus, Eriophorum virginicum, Rynchospora alba,* and *Sphagnum* sp. The pH readings of the soil in both areas were 4.0 or less and each population was located within ten miles of the coast.

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## Field Trip

**November 23, 1958. Van Cortlandt Park, N. Y.** The last official Torrey trip of the season, already in a winter setting, had a surprisingly large attendance. Luckily, Bill Rissanen was about to help out. We were particularly delighted to welcome as guests the youthful members of the City College Botanical Society. This time of the year, or a little earlier, is best for initiating the study of winter botany. The buds of shrubs and trees are fully formed, but still there are some leaves about to check identification. Furthermore, twigs and buds can be handled in the field with comfort, lacking later when the woods are too ice-bound. Autumn is also best for the study of wild fruits and seeds. In pointing out winter characters, the leader quoted a statement regarding the black oak: "Probably the most clinching characteristic of all lies in the fact that the twigs when chewed taste bitter and import a yellow color to the saliva. No other oak possesses this character." But a curiousity for testing this chew and spit technique by the group was nil, with one exception. Eleanor Yarrow did masticate the twig of a black oak, but stopped there and carried out no comparative study, at least in our presence. The leader himself can report indifferent results in his own trials: he seems to have no taste for oaks. Several flowers were found. The witch-hazel for one. Incidentally, it was clear to all, as we stood around the blossoming shrub, how its flowers were arranged: mostly in fours or threes, sessile in short-peduncled heads. The individual flowers have no pedicel. The New Illustrated Flora states that the flowers are "short-pediceled" where it means "short-peduncled," if it defines (it does) pedicle as the stalk of a single flower. In the northern limits of the West Woods in the Bronx, at the Westchester County line, we found several plants of *Guara biennis* in flower and fruit. The species is probably a newcomer in the area. *Wolffia columbiana* was examined through a hand-lense and elicited many open-mouthed "ahs!" by virtue of its being the tiniest flowering plant in the world—as though the smallest is basically any more significant than the slightly this side of average! Attendance 27. Leader, Joseph Monachino.

## Book Reviews

**Fifty Years of Botany.** Golden Jubilee Volume of the Botanical Society of America. Edited by William Campbell Steere. 638 pp. McGraw-Hill Book Company. New York. 1958. $10.00.

Forty authors writing about 50 years of development in forty fields of plant science say so much that a reviewer can no more than note briefly what the volume succeeds in doing. It presents a series of pictures of where we were in 1956 and 1957 when many of the articles were completed and published as special papers in the Golden Jubilee Volume of the American Journal of Botany. It was realized by the Committee, under the Chairmanship of Dr. Steere, that not only would many members of the Botanical Society like the whole group of papers, and more, in one volume, but that high school and college teachers and others interested in the broad aspects of plant science would appreciate being able to turn to one book where they could get a resumé and selected bibliographies of fields they have not been able to keep up with. The volume will also stand as a good marker of where we are and what we are thinking in mid twentieth century. Of course, no one volume can completely cover the extensive field, but the main roots, and stems are here and a fine assortment of branches. The authors are to be congratulated for having devoted their time and talents to the presentation of selected aspects of their fields. Included is the address on "The Early History of the Botanical Society of America" given by the Retiring President of the Society, Dr. Oswald Tippo, at the Dinner for all Botanists which celebrated the 50th anniversary of its founding. Also there are photographs of the 50 outstanding botanists who received the first Certificates of Merit to be awarded by the Society and the brief citations read when the awards were made.

At the great risk of omitting mention of what someone else may feel is one of the best papers let me mention a few titles and authors. From a Symposium on "Progress and Outstanding Achievement in Various Fields of Botany during the past Fifty Years" comes a paper on Phycology by G. F. Papenfuss, one on Mycology by William H. Weston,

one on "Taxonomy in an Age of Experiment" by Lincoln Constance, one on Paleobotany by Theodor Just, one on Morphology by A. J. Eames and one on Plant Physiology by F. W. Went. As samples of the portrayal of present thinking in particular fields there is Katherine Esau's "An Anatomist's View of Virus Diseases," Kenneth Rapers' "Microbes —Man's Mighty Midgets," "Problems in Preventing Plant-disease Epidemics" by E. C. Stakman, H. V. Younken's discussion of "Botany and Medicine," Kenneth Thimann's discussion of "Growth and Growth Hormones in Plants" and Paul B. Sears' article on "Botanists and the Conservation of Natural Resources."

That plants are to be enjoyed is not overlooked as is evident from H. B. Tukey's article on "Horticulture is a Green Carpet that Covers the Earth," the one by George S. Avery, Jr. on Botanic Gardens, and the one on "Arboreta and Botanical Gardens in the Field of Plant Sciences and Human Welfare" by R. J. Seibert. There is not space to enumerate the papers in ecology, cytology, genetics and others on aspects of plant pathology or plant physiology and those which point up ways of interesting students in botany such as on the one by Donald Culross Peattee "On the Popularization of Botany."

There is no doubt that all kinds of botanists and non-botanists who are interested in plants will find many parts of this handsome gold bound volume enabling them to understand better what botany is, how it has developed in the last 50 years, what is being thought and done now and what some of the future contributions to man's understanding and enjoyment of the world of plants will be. This is a book which should be in every university library available to present and future undergraduate and graduate students. It should be in high school libraries for biology teachers and for enthusiastic students. Public libraries and horticultural society libraries will find it fills the oft expressed desire of people interested to learn more from reading that which they can understand.—HARRIET B. CREIGHTON.

**Morphology of Plants.** By Harold C. Bold. 669 pages. Harper & Brothers, Publishers, New York, 1957.

Some one meeting me by chance the other day said, "Have you seen what Bold has done?" I enquired, innocently, what he had done. "Why, its old Curtis all over again!" Well, there is an element of truth in this, enough to make it worth quoting. The reference was, of course, to *The Nature and Development of Plants*, a work justly famous in its day, but long since obsolete. The present book takes us, group by group, over the same route through the plant kingdom, via the familiar "type method" (which, of course, must not be confused with the "type method" of the taxonomist). About 20 per cent of its pages are occupied by the morphology of algae, about 14 per cent by fungi, about the same for bryophytes; there is half the book. When we have dealt with psilophytes, lycopods, ferns (10 per cent), *Ginkgo*, conifers, *Gnetum*, *Ephedra*, and *Welwitschia*, we have just about 4 per cent left for the flowering plants—half the plant kingdom. I had the same sort of introduction to morphology myself, and it was some years before I discovered that flowering plants also were of morphological interest. I had hoped that Bold would give us a new emphasis. But perhaps I am all wrong. As the author has said to me, the flowering plants are treated in special courses on taxonomy, anatomy, etc. And this book is intended for undergraduates. Still . . .

Any textbook must be assessed with regard to the students who will (we hope) read it. This one is designed for a year course, offered to students whose introduction to botany was unduly condensed and who wish to go further in the science. It is essentially supplementary to an elementary text. It is, then, against the rather confused background of the teaching of elementary botany that this work must be surveyed. The "type method" has some obvious drawbacks. Are the "representative" species selected for description the same as those studied in the laboratory and discussed in lectures? If so, recent strictures on textbooks in general are relevant here. Should not a textbook, in fact, be designed to present topics *not* encountered in the classroom? And to what extent are the species studied really representative of their groups? How many students, I wonder, think that *Marchantia polymorpha* is a typical liverwort, because preparations of it are easily obtained from the supply houses? Bold, however, does escape to a considerable extent from the straitjacket of the method, treating a good variety of "types."

The novel feature of this book is the classification of the plant kingdom in 24 Divisions. We have long been familiar with the separation of the algae into a number of distinct phyletic lines. The tendency to divide parallels a similar evolution in classification of animals. The students of fungi and vascular plants have lagged in this trend towards a polyphyletic view; they have allowed all fungi to remain in one division and all vascular plants in another—this a monstrous omnium gatherum of plants certainly as distantly related as brown and red algae are related. Bold (true to his name) carries the process forward, separating ferns and lycopods, dismembering that hoary relic, the gymnosperms, and making all the resulting groups coordinate with each other and with the "phyla" of algae. He even splits the bryophytes into two divisions, which prompts the query: why not into three? Whether or not you agree—and many teachers, of course, will be shocked—this treatment represents, in my opinion, a healthy antithesis to the outworn classifications that are still being pushed down undergraduate throats.

In the vast field of plant morphology, it is almost impossible for a teacher to avoid errors of detail. A critic can find errors in this work; but they are certainly not striking nor serious. It is no part of a reviewer's task to point out such minor blemishes as I have found here. It is pleasant, rather, to testify to the wide reading and sound scholarship that went into the preparation of the book. In fact, when one disregards the general plan, any comparison with *The nature and development* is misleading and unjust. Morphology has come a long road since Curtis' day, and to survey the entire field is an almost inhuman task. Bold's exposition is lucid and philosophic, detailed without being overwhelming, illustrated by excellent drawings and photomicrographs (many of them original). The book is attractively produced and well printed. Whatever theories of pedagogy one subscribes to, there is no doubt that we have acquired a valuable work, one to which many classes of students will profitably turn. The author's own philosophy of teaching, incidentally, is partly revealed in his prefatory remarks "to the student," which deserve the attention of teachers as well.—H. W. RICKETT.

**The Physiology of Forest Trees.** A Symposium Held at the Harvard Forest April, 1957 under the auspices of the Maria Moors Cabot Foundation. Edited by Kenneth V. Thimann, Professor of Biology, Harvard University, with the assistance of William B. Critchfield and Martin H. Zimmermann. XVI + 678 pp. Illus. The Ronald Press Co., New York, N. Y. 1958. Price $12.00.

This is a record of a symposium consisting of 35 papers on tree physiology. The participants, 33 in all, were professors and botanists, especially plant physiologists, from many quarters of the globe—from New Zealand, Norway, Germany, England, Scotland, Canada and many parts of the United States. The proceedings were divided into five parts, as follows: 1. Water Relations and Sap Movement. 7 papers. II. Photosynthesis. 3 papers. III. General Biochemistry. 4 papers. IV. Mineral Nutrition. 2 papers. V. Phloem Transport. 3 papers. VI. Root Growth. 4 papers. VII. Other Growth Phenomena. 3 papers. VIII. Photoperiodism and Thermoperiodism. 4 papers. IX. Reproduction. 5 papers. An author index and a subject index are appended. The introduction, by Dr. Paul C. Mangelsdorf, contains an account of the Maria Moors Cabot Foundation for Botanical Research and its organization for the purpose of basic research on problems of forest genetics and methods of propagation of forest trees, and, more recently, on forest tree physiology. This is followed by a short description of the Harvard Forest by its Director, Prof. Hugh M. Raup.

It is of course impossible in the comparatively small space allotted to me, to review every one of these excellent and informative papers. I must select only a few which are of particular interest to me, and even these can not be treated thoroughly.

I have always been curious about the force and the conditions which govern the rise of sap in the wood of trees—in some cases to great heights—in the Redwood (*Sequoia sempervirens*) to as much as 364 ft.[1] So I turned at once to the first paper in Part II,

[1] Collingwood, G. H. and Warren D. Brush. Knowing your trees. Amer. Forest Assn. Washington, D. C. 1957. p. 46.

entitled "The Rise of Sap in Lianas" by Professor Per F. Scholander of the University of Oslo, Blindern, Norway. I found that he supports the now generally accepted transpiration-cohesion-tension theory.[2] A very simple explanation of this theory has been given as follows: If one places a drop of water on a glass slide and turns the slide upside down, the water drop being then on the *under* side, the drop does not fall off, but adheres, and likewise will adhere when one lifts the glass slide. If we substitute for the water drop the column of water in the vessels of the xylem or wood and for the lifting power the evaporation at the upper end of the column in the leaves then the situation becomes clear. Scholander refers to Briggs[3] as authority for the statement that the force needed to break a column of water by a pull or tension is equal to 200 atmospheres. Scholander states further; "This corresponds to a hydrostatic height many times greater than the tallest tree, and the energy available from the evaporation of water is ample for the lifting process. So the physical basis is quite adequate, but when we try to apply the theory to trees, we run into difficulties . . ." One is that an exact hydrostatic gradient, that is, a decreasing pressure of 1 atmosphere per 10 m. of elevation has not been demonstrated in trees. Further, a tension column can not exist if it contains gas (or air) bubbles. Somehow these must be eliminated. When we cut off a branch or even pluck a leaf, the sap does not all run out, nor does air enter, as might be expected. There must be some system of check valves to remedy such occurrences which so far is unexplained.

Professor Scholander chose woody vines for the study of the sap rise problem, convenient materials because they attain considerable heights and can be easily manipulated. The stems of *Vitis Labrusca* and a tall-growing species of *Tetracera* were chosen. Using a manometer at different heights of the vine, before the leaves come out in the spring, Scholander found the hydrostatic gradient to accord with the theory that the sap forms a pressure continuum throughout the vine, i.e. a decrease of 1 atmosphere every 10 m. Later, however, after the leaves come out, it was found that "toward the top the indicated pressures were usually greater than in the lower part of the vine." It is suspected that the difficulty lies with gases in bubble form in the sap stream. Dr. Scholander says "We are therefore faced with the necessity of demonstrating that a mechanism exists which can repair massive air seeding through the vessels and tracheids in tall northern trees." (p. 13) Another point which seems to be more or less overlooked is the presence of water in the cell walls. In some way this may have a bearing on the whole problem.

Using an aqueous solution of acid fuchsin, Dr. Kenneth H. Greenidge of the Forest Biology Laboratory of the Canadian Dept. of Agric. at Truro, Canada, has shown the rates of sap rise in our common trees. By cutting sections of the trunks at various levels and at various times after introduction of the dye, its rate of travel and extent of penetration are readily observed. The rate of rise varied in different species. In American Elm it was most rapid, varying from 35 to 141 ft. per hour. In Sugar Maple it was 5 to 14 ft. per hour.

The paper by Dr. Irving W. Bailey on the structure of tracheids in relation to the movement of liquids, suspensions, and undissolved gases is admirably written and illustrated and should be read by all who have any interest in coniferous species.

Many of us have been brought up in our college years on the doctrine that the xylem carries water and salts (solutes) up the stem and phloem carries "elaborated" foods up or down—mainly down. But recent studies have shown that it is not quite as simple as this.[4] The paper by Edward G. Bollard, of the Forest Research Station, Dept. of Scientific and Industrial Research, Auckland, New Zealand gives evidence of the transport of nitrogenous compounds such as aspartic acid, asparagine, glutamine, and many others in considerable amounts upwards from the roots, in the xylem. For this study the xylem sap was "extracted from 131 species (116 dicotyledons, 6 monocotyledons, 9 gymnosperms) all drawn from different families." Dr. Bollard says: "Incorporation of inorganic nitrogen into organic compounds is largely accomplished in the roots—the root system then supplying other parts of the tree with nitrogen in a variety of organic forms." Dr. Bollard is uncertain whether these nitrogenous compounds are the result of synthesis in the

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[2] Bonner, James and A. W. Galston. Principles of plant physiology. 1952. p. 116 ff.

[3] Briggs, L. J. Limiting negative pressure of water. Jour. Appl. Physics 21: 721–722. 1950.

[4] Meyer, Bernard S. and Donald B. Anderson. Plant physiology, 2nd ed. 1952. p. 537.

root or of the breakdown of root storage proteins "or perhaps from a combination of both processes."

The place or places in the plant where protein is manufactured has long been an enigma to botanists. To this reviewer it has always seemed that the cells in the growing points or other meristem—e.g. the cambium—would be the most logical places for the synthesis to occur. For the complex molecules of protein are closest in structure to the substance of protoplasm itself, so that protein synthesis might be regarded as only a step —the prelude as it were—to the formation of the living substance or protoplasm. The statement of Meyer and Anderson (l. c. p. 511) that protein can be formed in most living cells is in harmony with this. But where is the protein "factory" in the plant, if there is any such? Bollard (see above) implies that the roots may be at least one of the places. The paper by David Siminovitch and A. P. J. Chater of the Science Service in Ottawa, Canada, on "Biochemical Processes in the Living Bark of the Black Locust Tree in Relation to Frost Hardiness and the Seasonal Cycle" offers conclusive evidence that protein in the bark cells of the tree is connected with hardiness, i.e., resistance to cold. At the approach of winter there is a marked increase in the amount of protein of hardy species, Black Locust having been selected as an object for study. Conversely, in spring and summer the protein content is greatly decreased. As to proof that the protein is actually formed *in situ*, it is indicated that this has already been shown in earlier papers by the "McGill group".[5] In conclusion it is stated: "Metabolically, it is difficult to trace as yet the events leading to protein synthesis in the bark cells or to the limitation imposed on protein synthesis in ringed trees. It is even more difficult to discern the exact relation of the incorporation to true protein synthesis, although some such relationship is indicated by the studies in ringed trees and in tissue culture." Further, "the results obtained . . . increasingly point to hardening as being in part at least a problem in protein synthesis." I should add here that, regarding the connection of protein with frost resistance, the coagulation and/or plasmolysis incident to freezing, a process which involves withdrawal of water from the cells, are evidently less liable to happen with cells which are plentifully supplied with protein.

As to the *direction of flow* of organic solutions in the phloem, Martin H. Zimmermann, Lecturer at the Harvard Forest, Petersham, Mass. in the paper "Translocation of Organic Substances in the Phloem of Trees", inclines toward the "mass flow" theory of Münch that the flow of organic substances is in the direction of the place where the substances are used or converted (i.e. sugar into starch). Thus there is a constantly decreasing gradient of concentration and to this decreasing gradient is due the direction of flow.[6]

An interesting and able treatment of the mycorrhiza question is made by Visvaldis Slankis of the Canadian Dept. of Agric., Southern Research Station, Maple, Canada. His investigations confirm the work of McDougal and Dufrenoy (referred to on page 429) showing the formation of mycorrhizas to be associated with the exudation of auxin by the fungal symbiont. Depending upon the amount of auxin exuded by the fungus the coralloid or (with greater amount) the tubercle type of mycorrhiza is formed. Lankis states "However, the information obtained about the role of fungus-produced auxin in mycorrhizal symbiosis is still limited. So, for instance, we have no information about the role of this auxin in the cell metabolism of roots and its influence on the growth of the entire tree." Further, he says "We may assume that the root exudates in the rhizosphere induce a chemotropic response in these fungi."[7]

It has always seemed to me that this whole matter, i.e., the question of the pathogenicity of the fungus, could be solved once and for all experimentally by growing seedlings in two sets, one set provided with mycorrhizas and the other set in sterile soil, where no mycorrhizas could form, and comparing the growth of the trees after a sufficient number of years. Perhaps the problem of keeping the soil of the mycorrhiza-free set sterile makes the experiment too difficult. In the ensuing discussion of this paper Dr. Thimann suggested the investigation of mycorrhizas to see if they could fix nitrogen, an idea prompted by the resemblance of the tubercle mycorrhizas to leguminous nodules.

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[5] See Scarth, G. W. Cell physiological studies of frost resistance: a review. New Phytologist 43: 1–12. 1944.

[6] Cf. "Diffusional flow." Bonner and Galston. ibid. p. 164.

[7] See Graves, A. H. Chemotropism in Rhizopus nigricans. Bot. Gaz. 62: 337–369. 1916.

Dr. P. R. White of the Jackson Memorial Laboratory, Bar Harbor, Me., has an interesting paper on "An Epiphytotic Tumor of White Spruce, Picea glauca" in which he traces the cause to a single aberrant cell or cells in the primary cambium of the bud. By the continued growth of these cells in a tangential direction a tumor is produced. The salt spray of the ocean is surmised to be the exciting agent and in the case of other similar tumors found inland some excitant is likewise predicated.

In the paper on photoperiodism in relation to tree improvement by Scott S. Pauley of the School of Forestry of the University of Minnesota, the photoperiodism does not refer here to the flowering response, although that has been shown to exist in many woody species, but to the vegetative growth of woody plants. Length of day is a factor, he says, of "marked importance in the annual vegetative growth cycle of many woody species, particularly as it relates to the control exerted over the timing of physiological processes concerned with the onset of winter dormancy." Some of these "photoperiodic growth responses appear to be under strong genetic control and thus are subject to manipulation by natural or artificial selection." In general, when woody plants are moved north of their native habitat their period of growth is lengthened and resistance to early autumn frosts is decreased, while if they are moved southward where days are shorter the vegetative growth is shortened and resistance to cold is increased. Without going deeper into the argument, it is clear that on account of the variation in different individuals there is ample opportunity for natural and also for artificial selection to operate in the case of trees planted north or south of their native habitat. The paper is important for foresters who, naturally, are desirous of securing the maximum height growth and wood increment for their trees.

Philip F. Wareing, of the University of Manchester, England, has studied the development of the male and female cones in Scots pine (*Pinus sylvestris*) and finds four types of flowering in this species (p. 650). In general the "male" flowers develop on the weaker and older branches, the "female" on the more vigorous branches.

I should recommend the reading and study of this book not only by all forestry students but also by their teachers. For long years too little has been known about the physiology of trees or how they "work," in the same sense as an automobile or a watch "works." It is good to know that so many intelligent minds are devoting their time and energy to finding out these things, a development which has progressed gradually, especially through the last fifty years. The wealth of references appearing at the end of each paper is ample testimonial of this fact. In fact, these citations and the interesting discussions by the various workers—scientists, professors and lecturers—enhance the value of the book to a remarkable degree. Let the good work go on, and may we have other symposia in the not too far distant future.—ARTHUR H. GRAVES, Connecticut Agricultural Experiment Station, New Haven.

**Genetics Laboratory Manual.** By A. M. Winchester. 128 pages. Wm. C. Brown Company Publishers, 1958. $2.75.

This manual contains detailed laboratory instructions for use in a beginning genetics course. Although it is designed to be used with the author's "Genetics" (Houghton Mifflin Co. 1951), the material can be easily integrated with any one of the various texts. The experiments are intended to give the student practice in breeding and observing Drosophila and in tabulating and interpreting results. Statistical evaluation of experimental results is emphasized. Although most of the exercises are similar to those of other manuals of genetics, a few sections are of special interest. Instructions for the analysis of an unknown mutant, and experiments designed to determine the influence of such environmental factors as temperature, light, and diet on the penetrance and expressivity of certain characters may prove valuable for use in two semester courses. Also, there is an excellent section on human genetic traits, a subject always of interest to students. The print is especially large, and there are many fine photographs. Ample space for drawings, calculations, answers to questions, and tables is provided separately from the instructions so that these pages may be removed from the spiral-bound notebook and turned in for grading. Some instructors may feel, however, that the directions are too detailed, and

that blank pages would make for greater flexibility. No reference material is included. In general, the manual is a welcome addition to laboratory literature in the field.—MAXINE RUTH MOORE, Douglass College, Rutgers, the State University of New Jersey.

**Workbook for Field Biology and Ecology.** By Allen H. Benton and Wm. E. Werner, Jr. X+268 pages. Burgess Publishing Company. 1957. $2.75.

The authors represent the biology department of New York State College for Teachers (Albany) and Blackburn College (Carlinville, Ill.) respectively. They have collaborated earlier in writing "Principles of Field Biology and Ecology" (McGraw-Hill 1958). The two books do not depend upon each other. Topics in the table of contents of this book indicate 28 possible field trips or laboratory exercises. Some of these could easily occupy more than one period so there is ample material for a full year course. Covering both animals and plants, it would hardly be useful to devote less time to such a course. The work is divided into eight sections.

Section I deals with taxonomy, i. e., classification of organisms. In the animal kingdom the major group is Phylum and one wonders why this is replaced by Division in classifying plants, but at least the groups presented are in accord with modern usage. A key is provided to families of mammals of the United States but no key to any plant group is found though they are well represented in the References.

Section II describes some field techniques, largely methods of collection and preservation of specimens but seven ecological methods are included. Plant population analysis is a superficial, one-page treatment of quadrats and transects. There is no necessity for quadrats being square and certainly much useful information could be obtained beyond the number of each species present on the quadrat. The data sheets provide for "% area, growth type, importance" but there are no directions for taking such data. Animal population analysis receives equally short shrift. An introduction to the Lincoln-Peterson Index is useful.

Section III covers Terestrial Communities and Succession (plant and animal), seven communities—four in the forest succession. Section IV is devoted to Aquatic Communities and Succession, five communities. Section V, Population Studies, is limited to mammals, breeding birds, and reptiles. Section VI, Behavior Studies, is also limited to animals though plants have behavior characteristics, too. Section VII, Projects for Field Study, will assist only the laziest instructors and students, being merely a brief listing of examples which would better be left to the originality of the projecteer. Those depending upon the section for procedure will be let down for there is no indication of conferences, methods of taking and presenting data, preliminary reports, or the writing of a scholarly final treatment of the project. Section VIII is 46 pages dealing with Selected Literature, some of it "free and inexpensive biological literature." The most valuable inovation occurs in this section where most of the citations are spaced apart, providing for student annotations as they are consulted.

There are questions for thought and guidance, blank tabulations, and even completely blank pages for student notes, though probably not enough for ambitious students. There is a problem here because notes taken in the field are hasty, illegible, and practically unintelligible after they get cold. Should the student fill the pages with this or carry note paper and transcribe? The book is spiral bound and hence opens flat or all the way around, facilitating note writing on the left hand page. It is large-pocket sized, 5.5″ × 8.25″ pages. It might be well to remember that transparent plastic sacks are available and useful to protect the book afield if it rains.

Although the book may appear broad but not deep in its coverage, one admits that the able instructor and willing student can readily plow to greater depth. Perhaps this is a better practice than trying to extract the essentials from a book that is overburdened with details.—JOHN A. SMALL.

**How to Identify Plants.** By H. J. Harrington, Illustrated by L. W. Durell. 209 pages, Fig. 1–533. Sage Brooks, Denver. 1957. $3.00.

The authors are both from Colorado State University and Dr. Harrington is author of "Manual of the Plants of Colorado," see Bull. Torrey Club 81: 513–514, 1954. Many instructors may find it hard to realize that a student beginning plant identification after some study of general botany is sufficiently uninformed to need this book. Nevertheless, extending the book account and devoting two weeks to this book, then keeping it handy for reference, may well pay big dividends when it comes to using the manuals. It will aid in selecting a manual for any part of North America though omissions of your favorite one may be found. The strongest part of the book is the extensive list of terms which the student should comprehend before starting the use of keys. Terms are simply defined and ably illustrated. An even longer list, also illustrated, is available for consultation when needed. The book will therefore supplement or supersede the glossary of any manual. In addition there are early chapters to get one in the mood for plant identification and later ones dealing with the use of keys as well as with collecting and pressing plants. A little less glue and more about liquid plastic for herbarium mounting might be suggested here. The book should certainly be around any herbarium or laboratory of taxonomy. It is hard covered, firmly cloth bound, photo-printed—J. A. S.

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# INDEX TO AMERICAN BOTANICAL LITERATURE

COMPILED BY

LAZELLA SCHWARTEN

WITH THE COLLABORATION OF THE EDITOR OF BRITTONIA

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